NASA/SDSU Geopositional Characterization

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Outline

- Ground Reference Sites
  - Brookings, SD
  - Stennis Space Center, MS
- Methods
- IKONOS Characterization
  - Data Collections
  - Results
- QuickBird Characterization
  - Data Collections
  - Results
- OrbView Characterization
  - Data Collections
  - Results

Characterization Overview

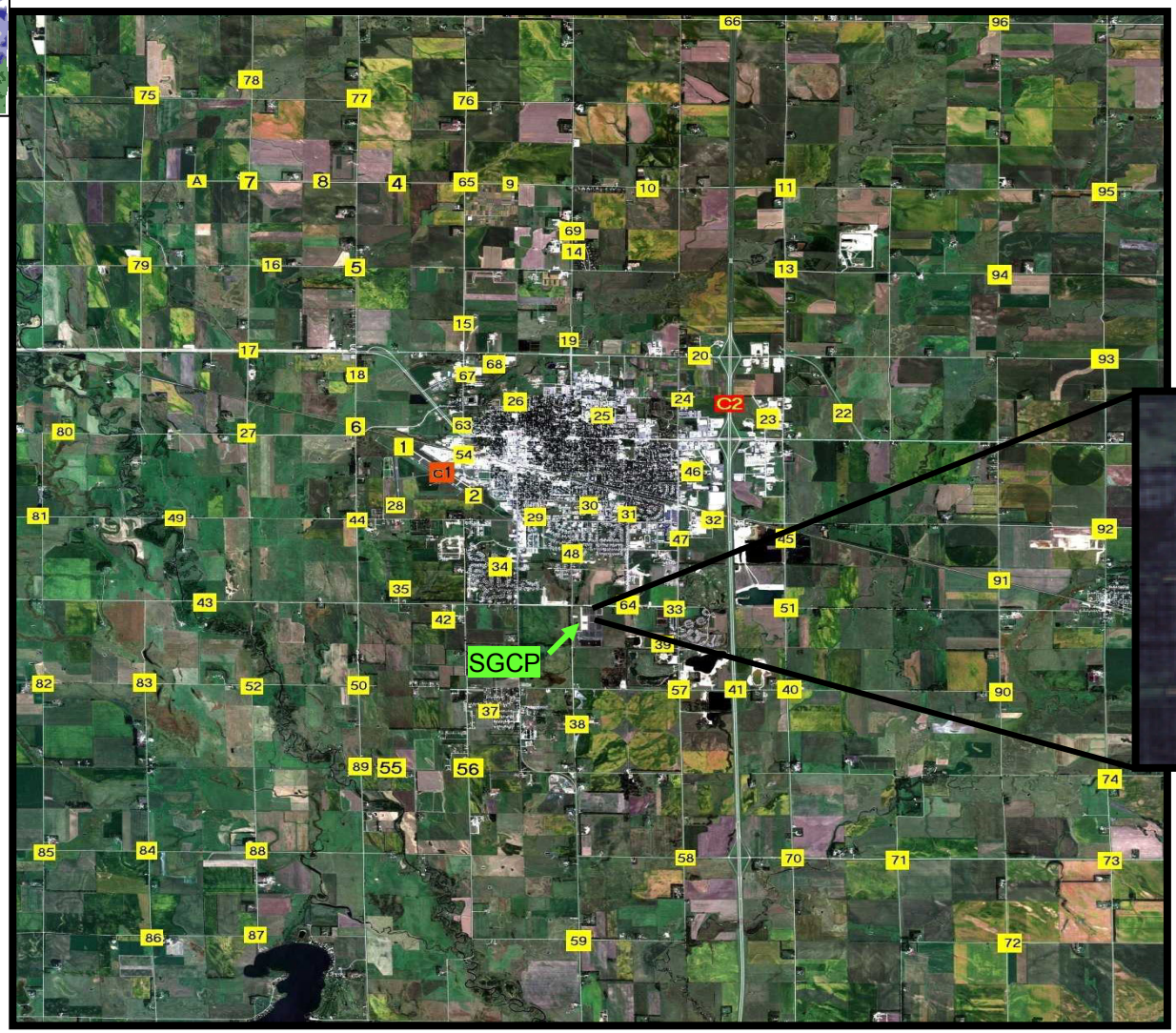
- Objective
  - Compare vendor-provided image coordinates with known references visible in the imagery
- Approach
  - Use multiple, well-characterized sites with >40 ground control points (GCPs); sites that are
    - Well distributed
    - Accurately surveyed
    - Easily found in imagery
  - Perform independent characterizations with independent teams. Each team has slightly different measurement techniques and data processing methods.
    - NASA Stennis Space Center
    - South Dakota State University

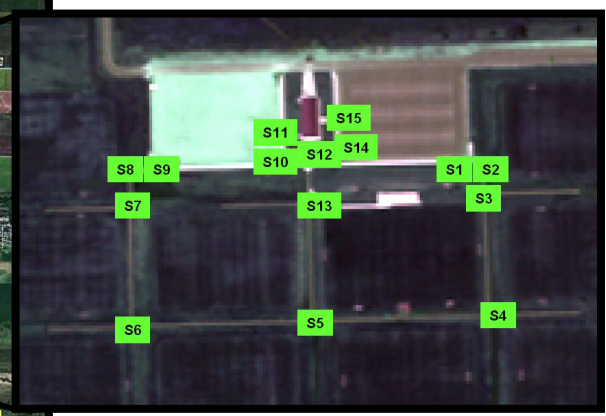
Data Providers

- DigitalGlobe, Inc.
  - Imagery acquired by the QuickBird sensor
- GeoEye™
  - Imagery acquired by the OrbView-3 and IKONOS sensors

Sites

Brookings Targets

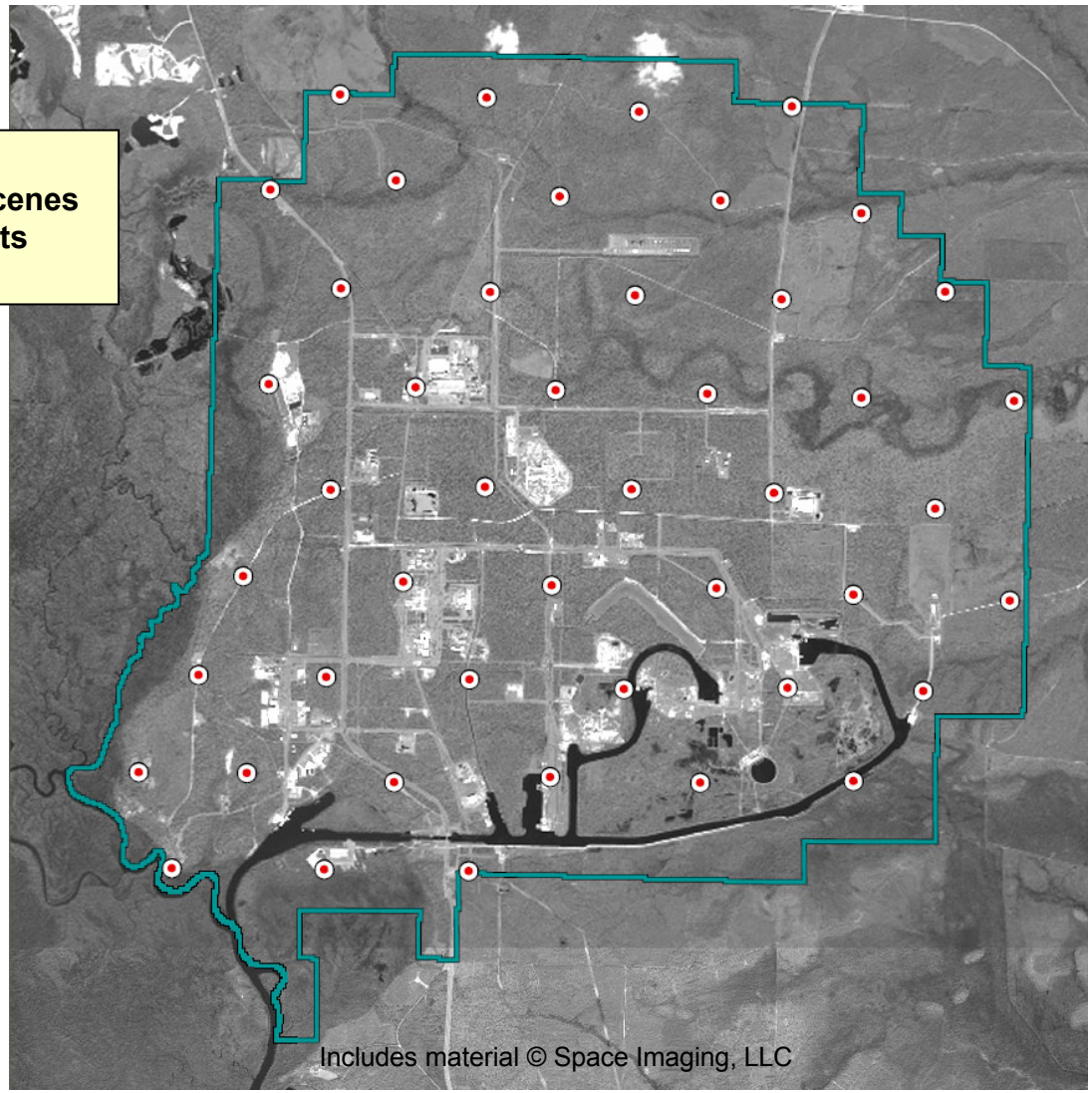




GCP Locations Base Stations Soccer Field GCP Locations

SSC Targets

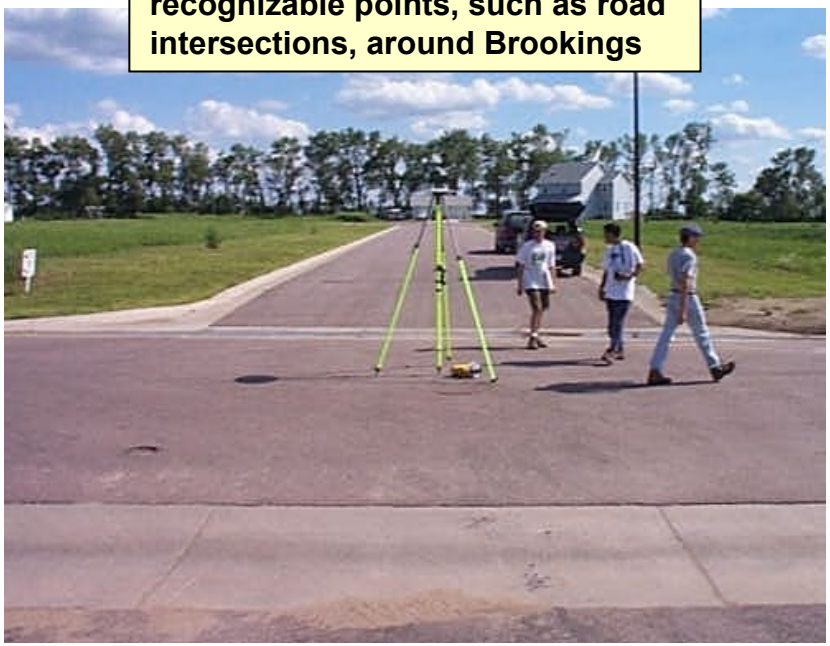
2 SEP 2005
IKONOS *Geo* scenes with SSC Targets Overlaid



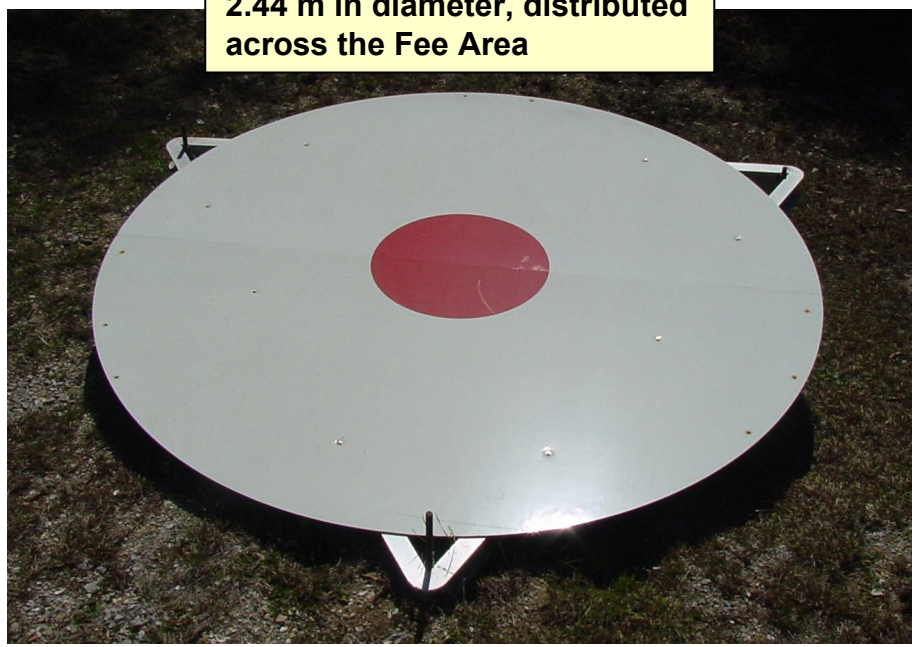
Brookings and Stennis Ground Control

Stennis Space Center

SDSU uses a distribution of 96 recognizable points, such as road intersections, around Brookings



SSC uses 45 circular targets, 2.44 m in diameter, distributed across the Fee Area

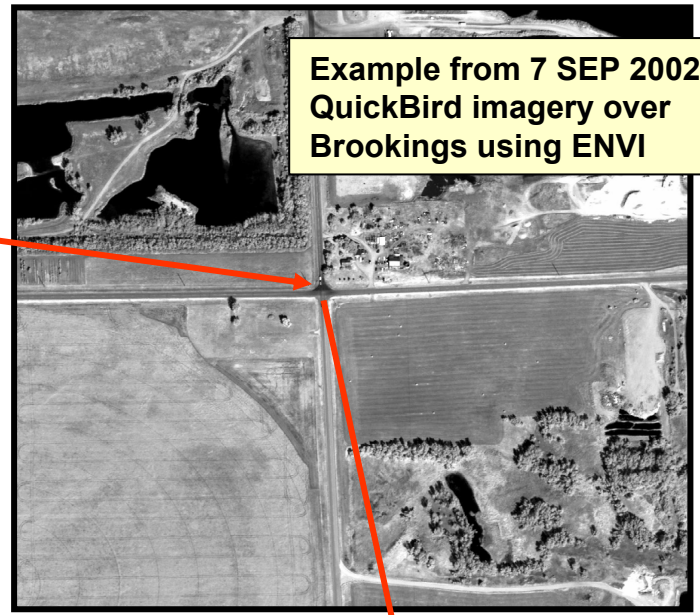


Both sets of GCPs were real-time kinematic GPS-located by the SSC survey team to absolute horizontal accuracies in the 3–6 cm range

Methods

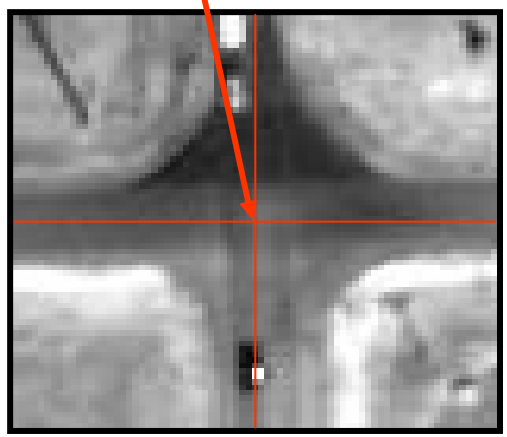
Finding Image Coordinates

Step 1



Example from 7 SEP 2002 QuickBird imagery over Brookings using ENVI

Step 2



Step 3

Disp #1 (8749.250,16600.250) Scrn: R:110 G:110 B:110

Projection: UTM Zone #14 North

Map: 678122.55E, 4904054.85N Meters

LL: 44°16'4.58"N, 96°46'5.70"W

Data: 249

Cursor Location/Value of Point 33

Additional Notes on Methods

- At South Dakota State University, images were analyzed by three individuals using ENVI® software
  - Visible points are determined for the group
  - Each individual finds points independently
  - If individual mistakes are found, individual is asked to re-do the point in question
  - Final image points are averaged before comparison with reference coordinates and generation of results
- SSC images were analyzed by a single individual using ERDAS IMAGINE® software to select image coordinates and using MATLAB® to generate results
  - Results are reviewed for indications of mistakes

QuickBird Geopositional Characterization

QuickBird Acquisitions

- Brookings, SD
  - 30 AUG 2004
  - 5 OCT 2004
  - 22 JUN 2005
  - 18 OCT 2005

- Stennis Space Center, MS
  - 23 JAN 2004
  - 28 JAN 2004
  - 21 JUL 2004
  - 17 JAN 2005
  - 12 MAR 2005
  - 6 SEP 2005

Scientific Data Purchase Specifications for QuickBird Products Assessed

- *Standard* (2A) imagery products (PAN & Multispectral)
  - "Standard Imagery products are radiometrically corrected, sensor corrected, geometrically corrected, and mapped to a cartographic projection…Geometric corrections remove spacecraft orbit position and attitude uncertainty, Earth rotation and curvature, and panoramic distortion…Standard Imagery has a coarse DEM applied to it, which is used to normalize for topographic relief with respect to the reference ellipsoid. The degree of normalization is relatively small, so while this product has terrain corrections, it is not considered orthorectified."
  - 23 meters CE_{90} (see next slide)

QuickBird *Standard* Specification Note

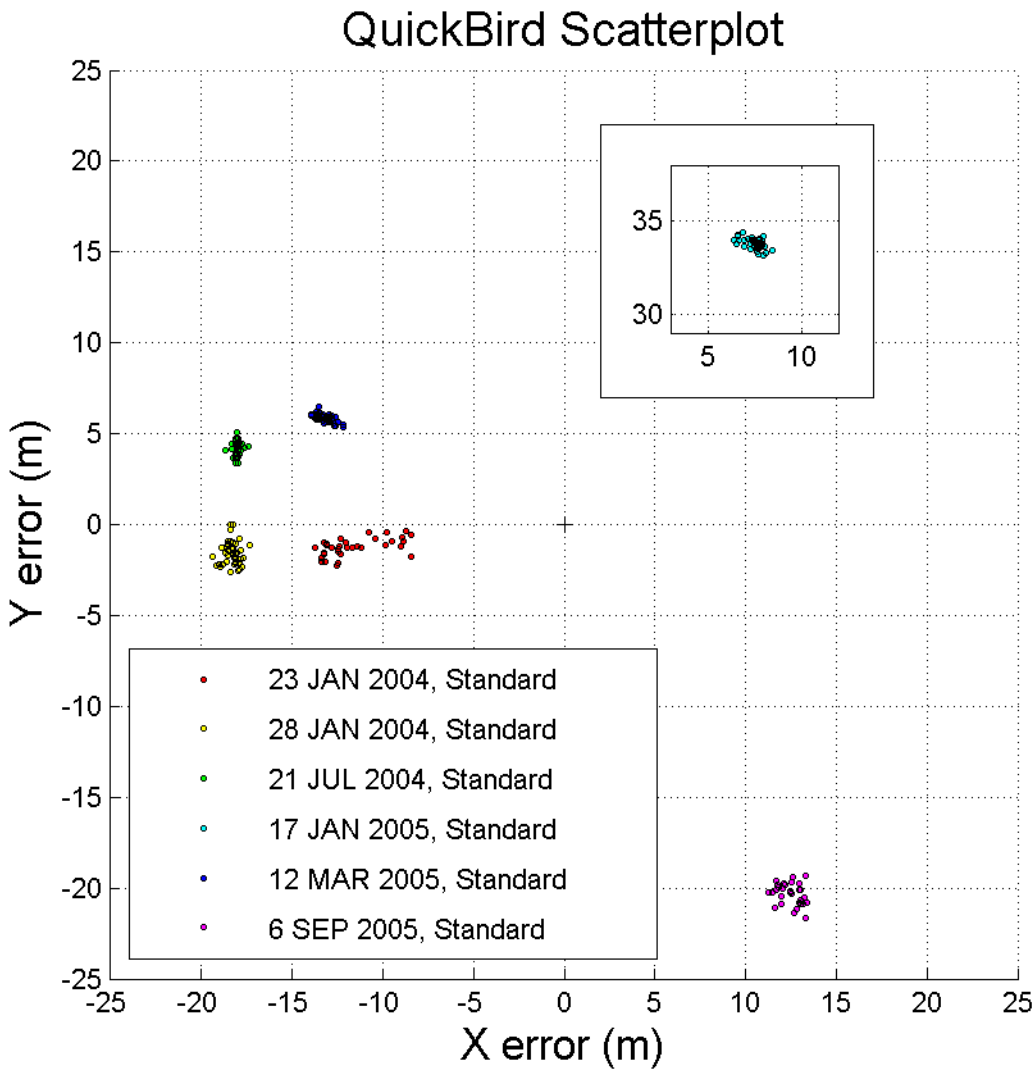
Accuracies: Standard Imagery products have an average absolute geolocation accuracy of 23-meter CE90%, excluding any topographic displacement and off-nadir viewing angle. Ground location is derived from refined satellite attitude and ephemeris information without requiring the use of Ground Control Points (GCPs).[1]

[1] DigitalGlobe, 2006. *QuickBird Imagery Products - Product Guide.* Revision 4.7. February 3, p. 19. http://www.digitalglobe.com/downloads/QuickBird%20Imagery%20Products%20-%20Product%20Guide.pdf (accessed March 10, 2006).

SSC 2004-2005 QuickBird PAN

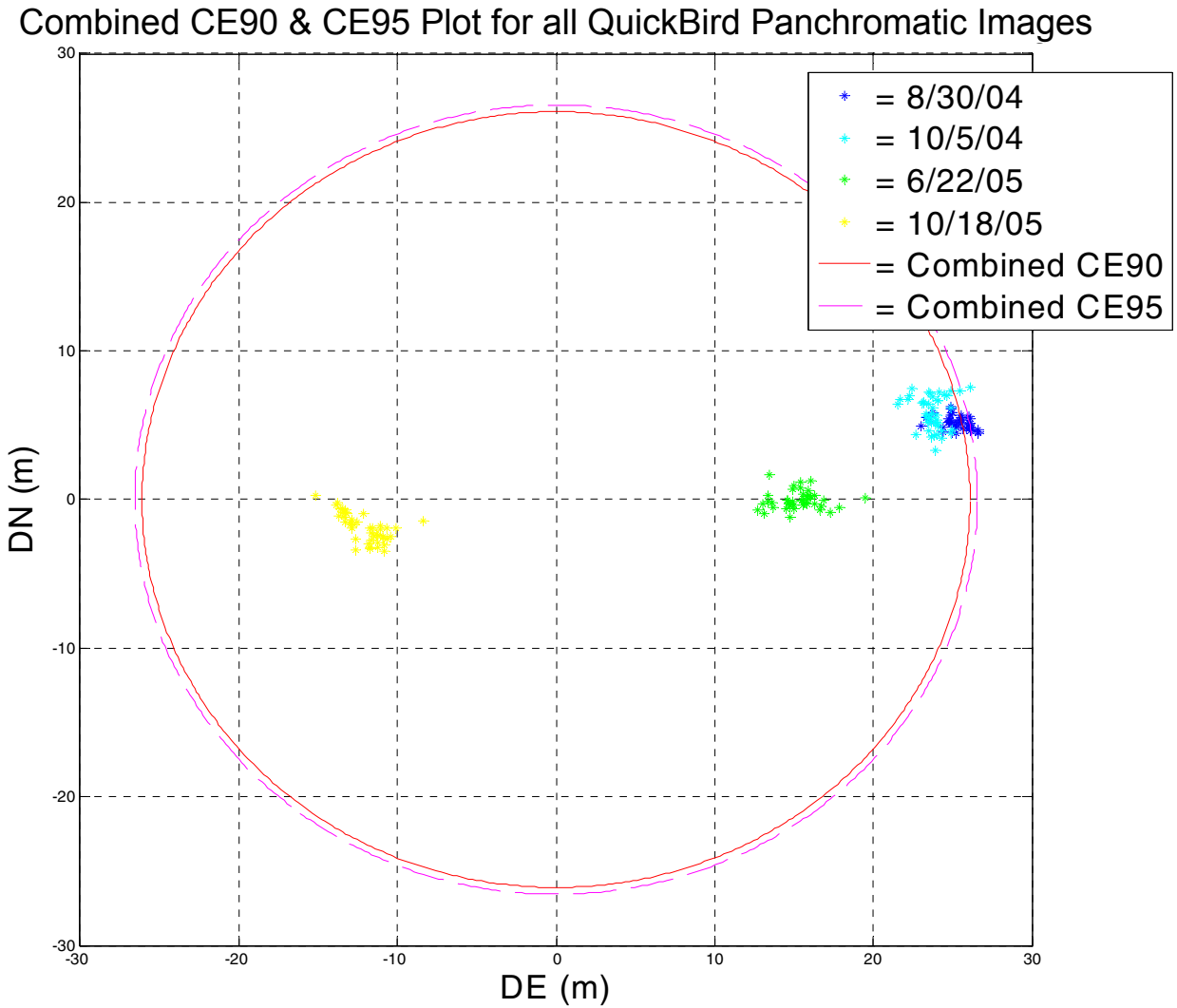
Stennis Space Center

Standard



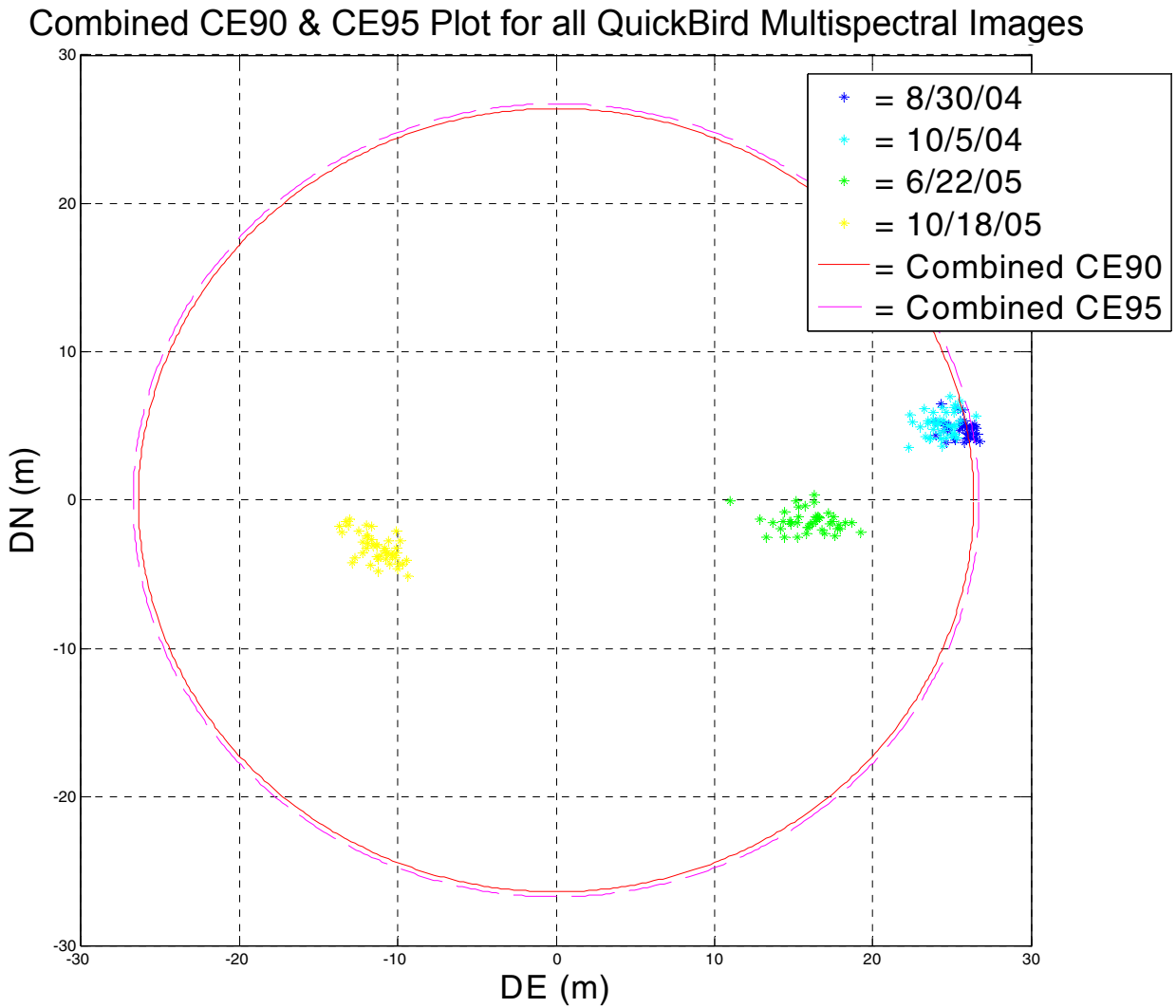
SDSU 2004-2005 QuickBird PAN *Standard*

QuickBird Panchromatic
Combined
CE90 = 26.10 m
CE95 = 26.56 m



SDSU 2004-2005 QuickBird Multispectral *Standard*

QuickBird Multispectral
Combined
CE90 = 26.39 m
CE95 = 26.72 m



Summary

QuickBird Product	Acquisition Date	Elevation Angle (deg.)	Horizontal Bias (m)	Circular Std. Error (m)	Empirical CE_{90} (m)	Empirical CE_{95} (m)
QuickBird Panchromatic Standard	23 JAN 2004	73.0°	11.58	1.11	13.36	13.49
	28 JAN 2004	74.6°	18.37	0.53	18.98	19.21
	21 JUL 2004	85.9°	18.47	0.31	18.75	18.84
	30 AUG 2004	83.2°	25.76	0.66	26.66	26.99
	5 OCT 2004	76.1°	24.50	1.01	25.62	25.93
	17 JAN 2005	81.1°	34.60	0.36	34.87	34.95
	12 MAR 2005	78.0°	14.39	0.34	14.99	15.16
	22 JUN 2005	72.5°	15.31	0.97	16.71	17.31
	6 SEP 2005	48.6°	23.84	0.61	24.73	24.85
	18 OCT 2005	73.2°	12.28	1.12	13.60	13.80
QuickBird Multispectral Standard	30 AUG 2004	83.2°	26.05	0.66	26.86	26.94
	5 OCT 2004	76.1°	24.94	0.88	25.98	26.27
	22 JUN 2005	72.5°	16.06	1.15	17.97	18.32
	18 OCT 2005	73.2°	11.80	1.06	13.34	13.55

- The mean CE_{90} of QuickBird panchromatic *Standard* images (excluding 6 SEP 2005 because of low elevation angle) was 21.9 m
  - 95% confidence interval from 16.2 m to 27.6 m
- The mean CE_{90} of QuickBird multispectral *Standard* images was 21.0 m
  - 95% confidence interval from 9.1 m to 33.0 m
- Three of nine acquisition dates with reasonable elevation angles had estimated CE_{90} above the Scientific Data Purchase specification of 23 m (no clear relationship with elevation angle)

OrbView-3
Geopositional Characterization

OrbView-3 Acquisitions

- Brookings, SD
  - 30 AUG 2004
  - 8 OCT 2004
  - 18 JUL 2005
  - 7 OCT 2005

- Stennis Space Center, MS
  - 6 NOV 2004
  - 12 APR 2005
  - 2 SEP 2005
  - 29 DEC 2005

GeoEye Self-Stated Specifications for OrbView-3 Products Assessed

- *GEO Express* PAN configuration
  - Geopositional information based on real-time downlinked telemetry only
  - 60 meters CE_{90} (see next slide)
- *GEO Enhanced* PAN configuration
  - Geopositional information based on refined GPS ephemeris and post-processed attitude data
  - 25 meters CE_{90} (see next slide)
- *ORTHO 1:50K* PAN configuration
  - *ORTHO* geopositional processing adds correction for the effects of systematic distortions, Earth rotation and curvature effects, variations in orbital altitude, and variations in the Earth's surface
  - 25 meters CE_{90} (see next slide)

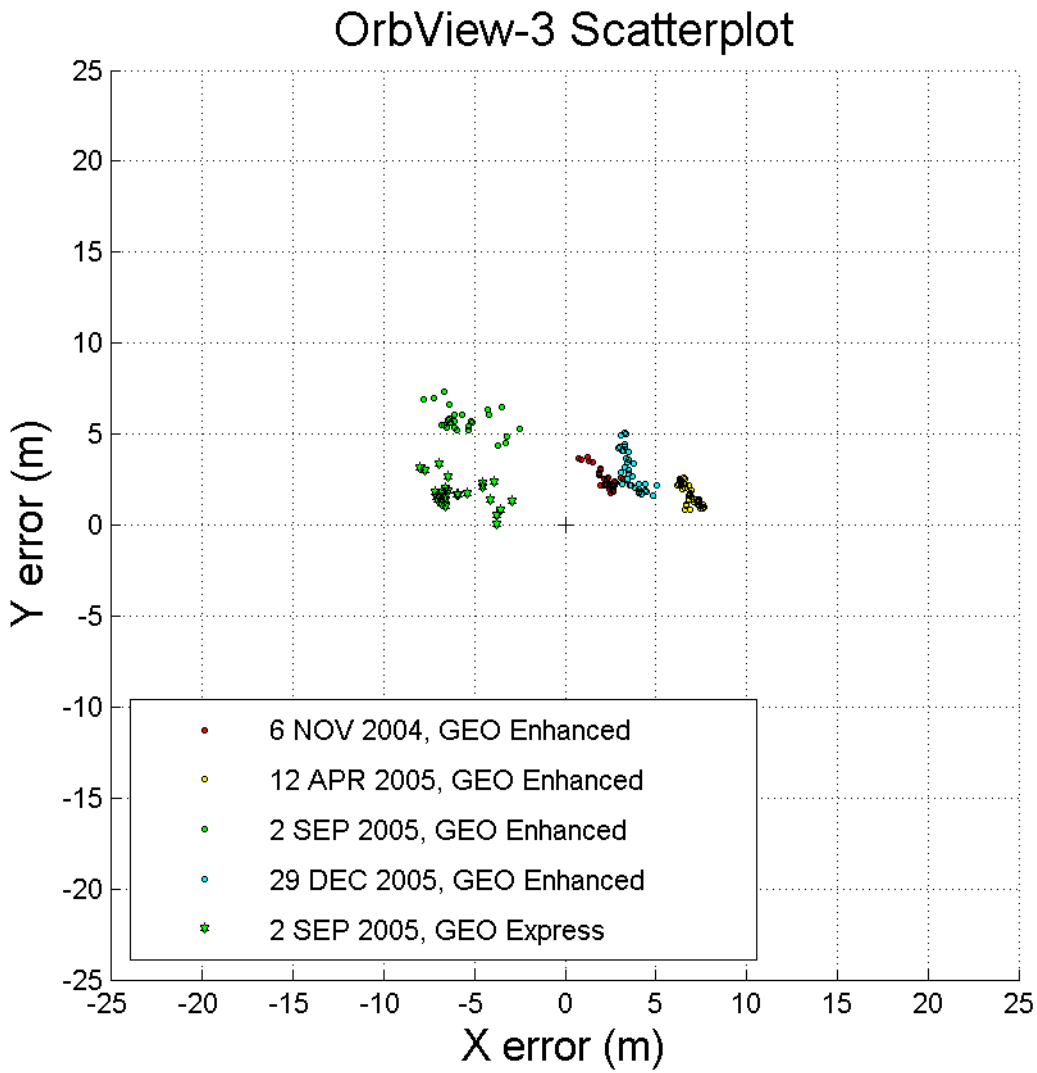
OrbView-3 *GEO* Specification Note

Stennis Space Center

NOTE: While the geocorrected image is presented in a map-like manner and is delivered with a reference point (corner coordinate) and spacing parameters, geographic coordinates should be derived from the image by using the supplied 3-D RFCs and not by using the corners and spacing. The corner coordinates and spacing should only be used for deriving gross geographical positions. In most cases, the accuracy of coordinates derived using the corner coordinates and spacing will not meet the product accuracies specified above. On the other hand, coordinates of points derived using the 3-D RFCs along with a stereomate or suitable elevation data will allow determination of latitude and longitude to the specified accuracies. In addition, using the RFCs, it is possible to improve accuracies and refine the geopositioning further by introducing additional images and/or control points in the solution.[1]

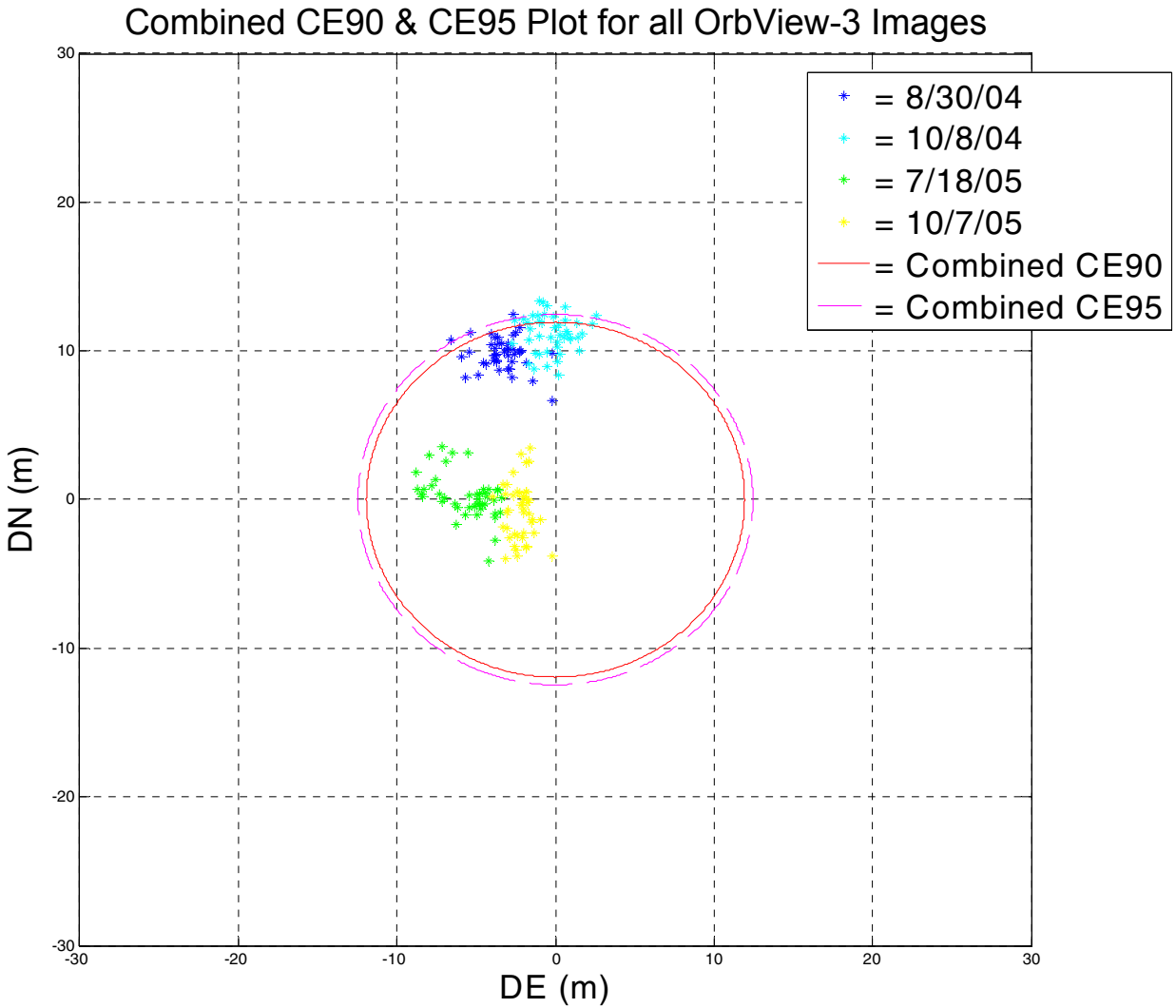
[1] GeoEye, 2006. *OrbView-3 Commercial Satellite Imagery Product Catalog.* January 23, p. 6. http://www.orbimage.com/docs/OV-3_Catalog_1_25_06.pdf (accessed March 10, 2006).

SSC 2004-2005 OrbView-3 *GEO*



SDSU 2004-2005 OrbView-3 *ORTHO 1:50K*

OrbView-3
Combined
CE90 = 11.93 m
CE95 = 12.45 m



Summary

OrbView-3 Product	Acquisition Date	Elevation Angle (deg.)	Horizontal Bias (m)	Circular Std. Error (m)	Empirical CE_{90} (m)	Empirical CE_{95} (m)
OrbView-3 *GEO Enhanced*	6 NOV 2004	81.2°	3.38	0.55	3.88	4.05
	12 APR 2005	86.4°	7.06	0.50	7.52	7.65
	2 SEP 2005	77.5°	7.97	1.04	9.79	10.11
	29 DEC 2005	86.9°	4.75	0.82	5.53	5.98
OrbView-3 *GEO Express*	2 SEP 2005	77.5°	6.10	1.09	7.65	8.35
OrbView-3 *ORTHO 1:50K*	30 AUG 2004	80.9°	10.45	1.19	11.76	12.46
	8 OCT 2004	75.7°	11.23	1.24	12.67	13.08
	18 JUL 2005	79.2°	5.82	1.54	8.38	8.54
	7 OCT 2005	82.3°	2.96	1.30	3.99	4.18

- The mean CE_{90} of OrbView-3 *GEO Enhanced* images was 6.7 m
  - 95% confidence interval from 2.0 m to 11.4 m
- The mean CE_{90} of OrbView-3 *ORTHO 1:50K* images was 9.2 m
  - 95% confidence interval from 2.0 m to 16.4 m
- Interestingly, for the single date of comparison, the *GEO Express* product performed slightly better than the *GEO Enhanced* product
- All OrbView-3 images characterized in this reporting period met ORBIMAGE's self-stated specifications for any *GEO* product configuration

IKONOS
Geopositional Characterization

IKONOS Acquisitions

- Stennis Space Center, MS
  - 15 DEC 2004
  - 17 JAN 2005
  - 15 APR 2005
  - 2 SEP 2005
  - 13 SEP 2005

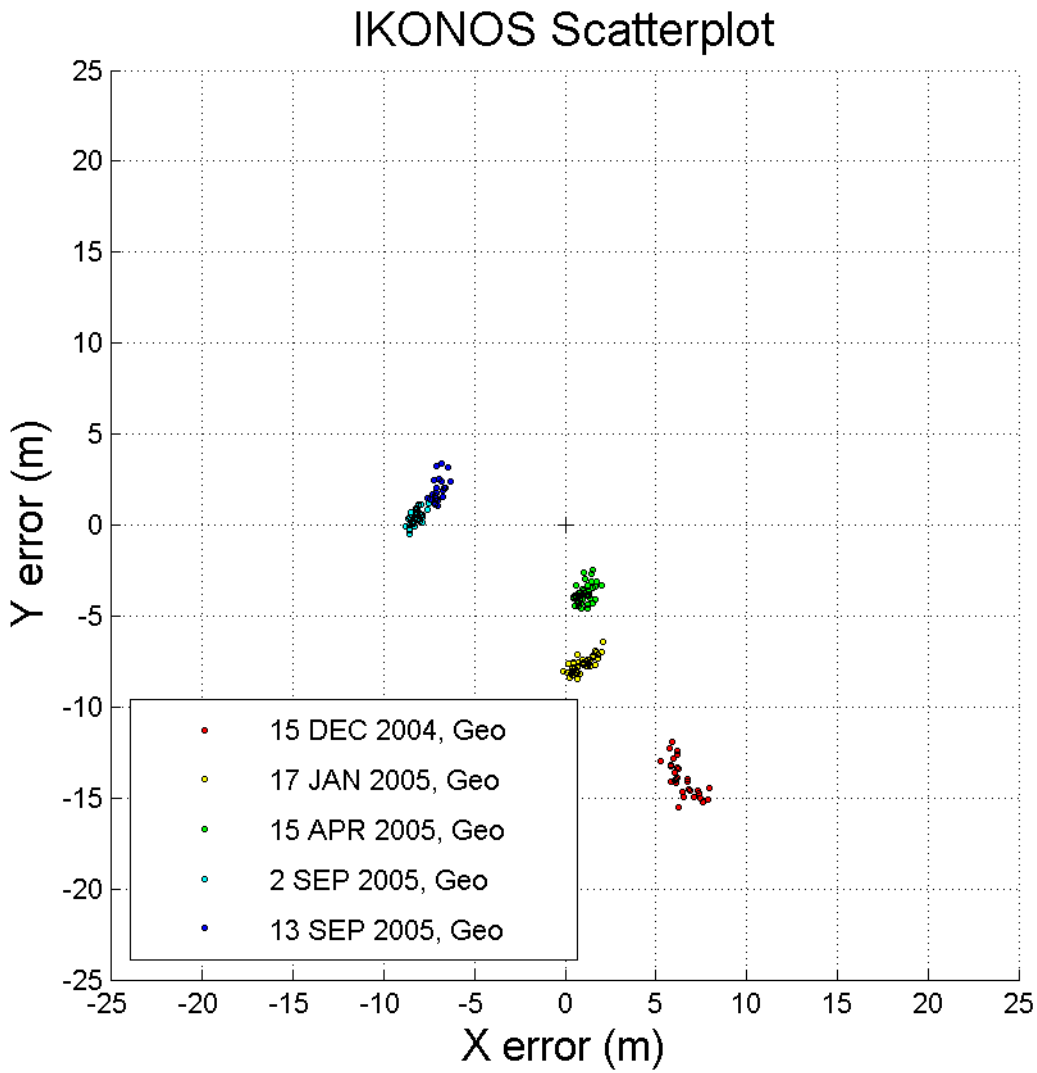
GeoEye Self-Stated Specifications for IKONOS Imagery Assessed

- *Geo*
  - Geopositional information based on “correction process that removes image distortions introduced by the collection geometry and then resamples the imagery to a uniform ground sample distance (GSD) and a specified map projection. Because Geo images are not orthorectified, their accuracy is limited by terrain displacement.” [1]
  - “Accuracy: 15m CE90 not including effects of terrain. True accuracy including effects of terrain displacement, may vary several hundred meters in regions of high relief.” [2]

[1] Space Imaging, Inc., 2005. *IKONOS Image Products and Product Guide.* p. 3. http://www.spaceimaging.com/whitepapers_pdfs/IKONOS_Product_Guide.pdf (accessed February 13, 2006).

[2] Space Imaging, Inc., 2005. *Geo 1m & 4m (Technical Overview).* http://www.spaceimaging.com/products/ikonos/geo_techspec.htm (accessed March 10, 2006).

SSC 2004-2005 IKONOS *Geo*



Summary

IKONOS Product	Acquisition Date	Elevation Angle (deg.)	Horizontal Bias (m)	Circular Std. Error (m)	Empirical CE_{90} (m)	Empirical CE_{95} (m)
IKONOS *Geo*	15 DEC 2004	68.9°	15.40	0.81	16.72	17.00
	17 JAN 2005	86.6°	7.73	0.49	8.18	8.29
	15 APR 2005	72.7°	3.93	0.44	4.51	4.60
	2 SEP 2005	82.6°	8.20	0.40	8.59	8.61
	13 SEP 2005	80.7°	7.27	0.49	7.62	7.74

- The mean CE_{90} of IKONOS panchromatic *Geo* images was 9.1 m
  - 95% confidence interval from 2.8 m to 15.4 m
- The 15 DEC 2004 image, with a CE_{90} of 16.7 m, was about 10% above the self-stated GeoEye specification of 15 m

Questions?

Further Information

South Dakota State Analyses

QuickBird | OrbView-3

SSC Analyses

IKONOS | QuickBird | OrbView-3

Extended Summary

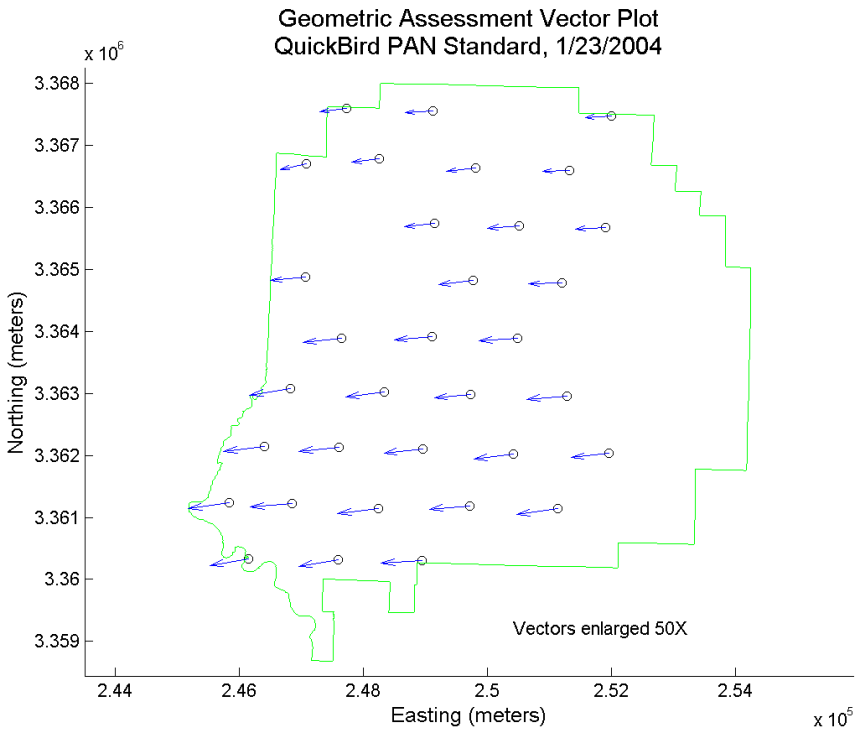
Participation in this work by Science Systems and Applications, Inc., was supported by NASA at the John C. Stennis Space Center, Mississippi, under Task Order NNS04AB54T.

Backup

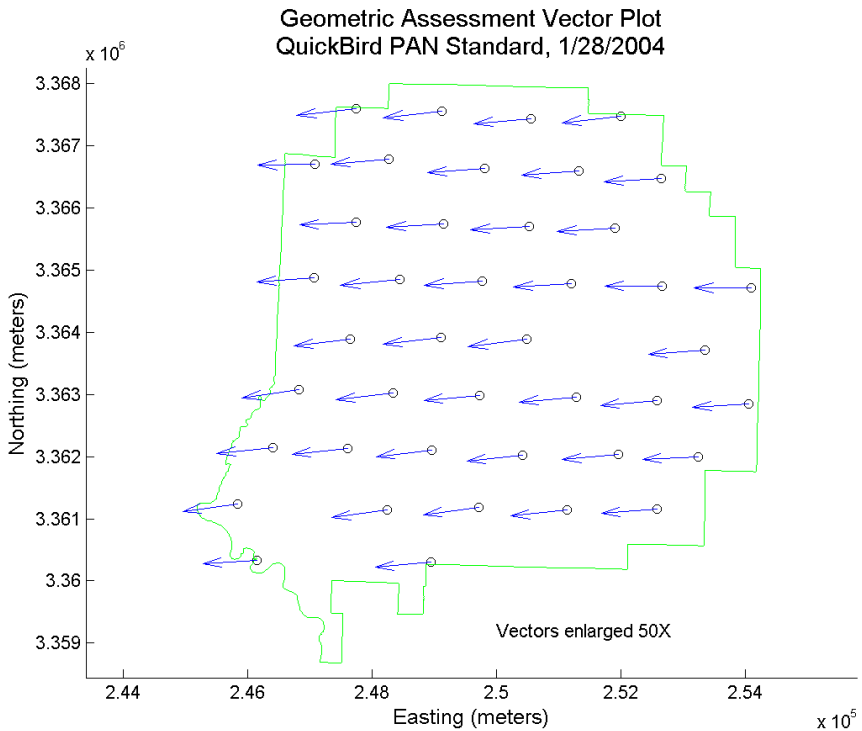
SSC – QuickBird PAN *Standard*

Stennis Space Center

23 JAN 2004
CE_{90}: 13.36 m
CE_{95}: 13.49 m
Circular Standard Error: 1.11 m



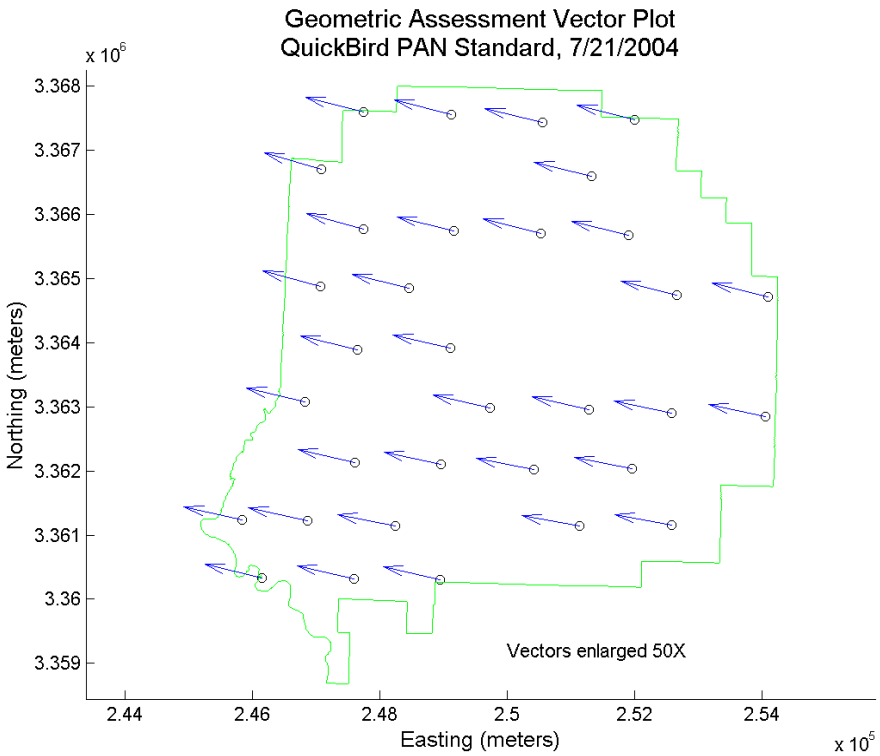
28 JAN 2004
CE_{90}: 18.98 m
CE_{95}: 19.21 m
Circular Standard Error: 0.53 m



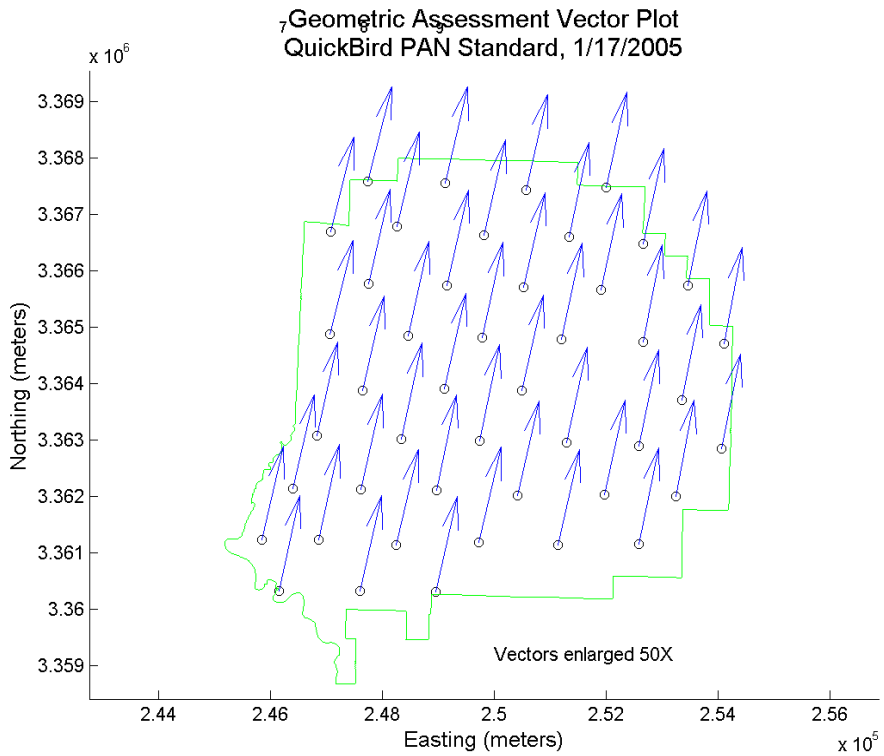
SSC – QuickBird PAN *Standard*

Stennis Space Center

21 JUL 2004	
CE_{90}:	18.75 m
CE_{95}:	18.84 m
Circular Standard Error:	0.31 m



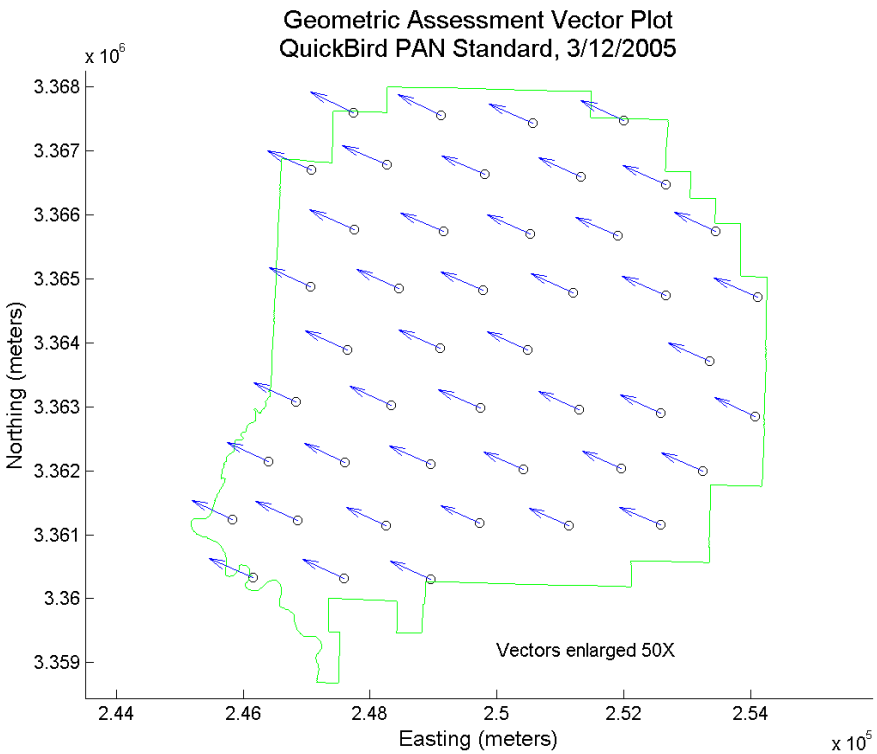
17 JAN 2005	
CE_{90}:	34.87 m
CE_{95}:	34.95 m
Circular Standard Error:	0.36 m



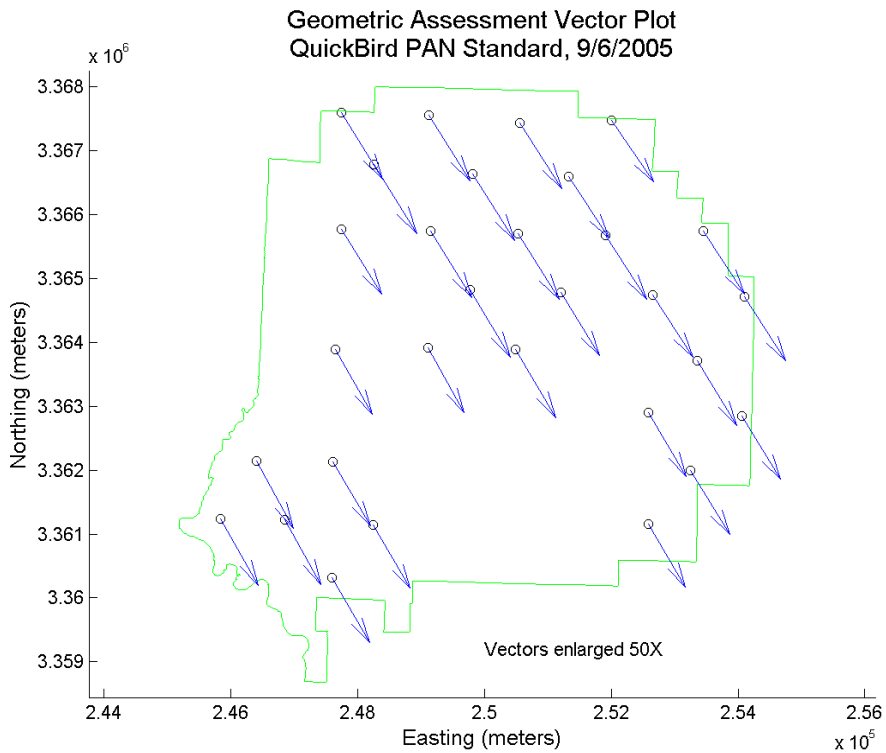
SSC – QuickBird PAN *Standard*

Stennis Space Center

12 MAR 2004
CE_{90}: 14.99 m
CE_{95}: 15.16 m
Circular Standard Error: 0.34 m



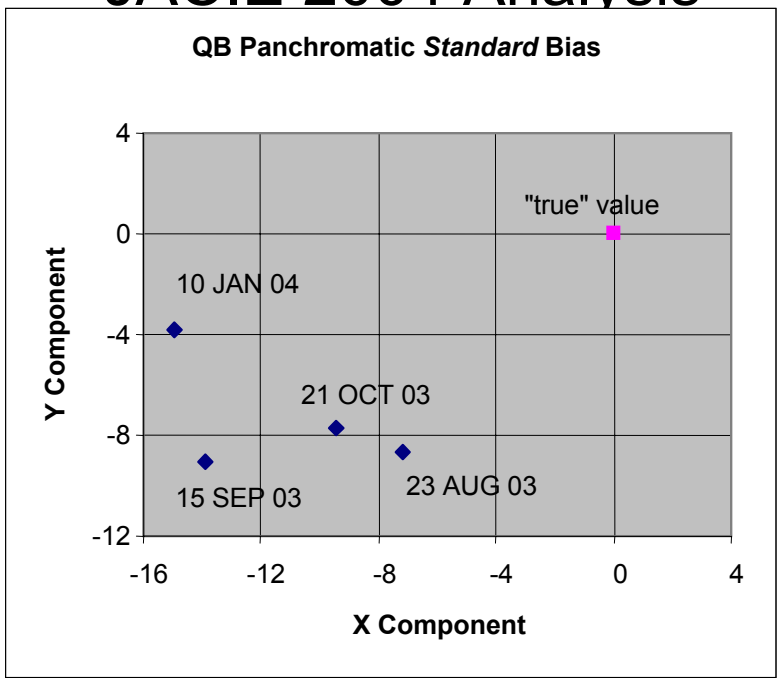
6 SEP 2005*
CE_{90}: 24.73 m
CE_{95}: 24.85 m
Circular Standard Error: 0.61 m



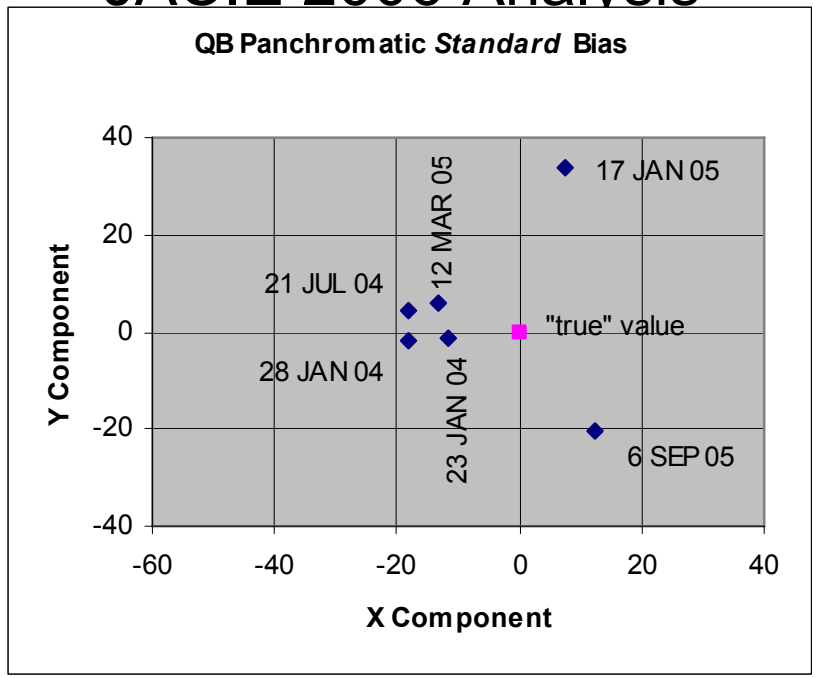
Satellite viewing angle of 48.6°

QuickBird Bias Trend

JACIE 2004 Analysis

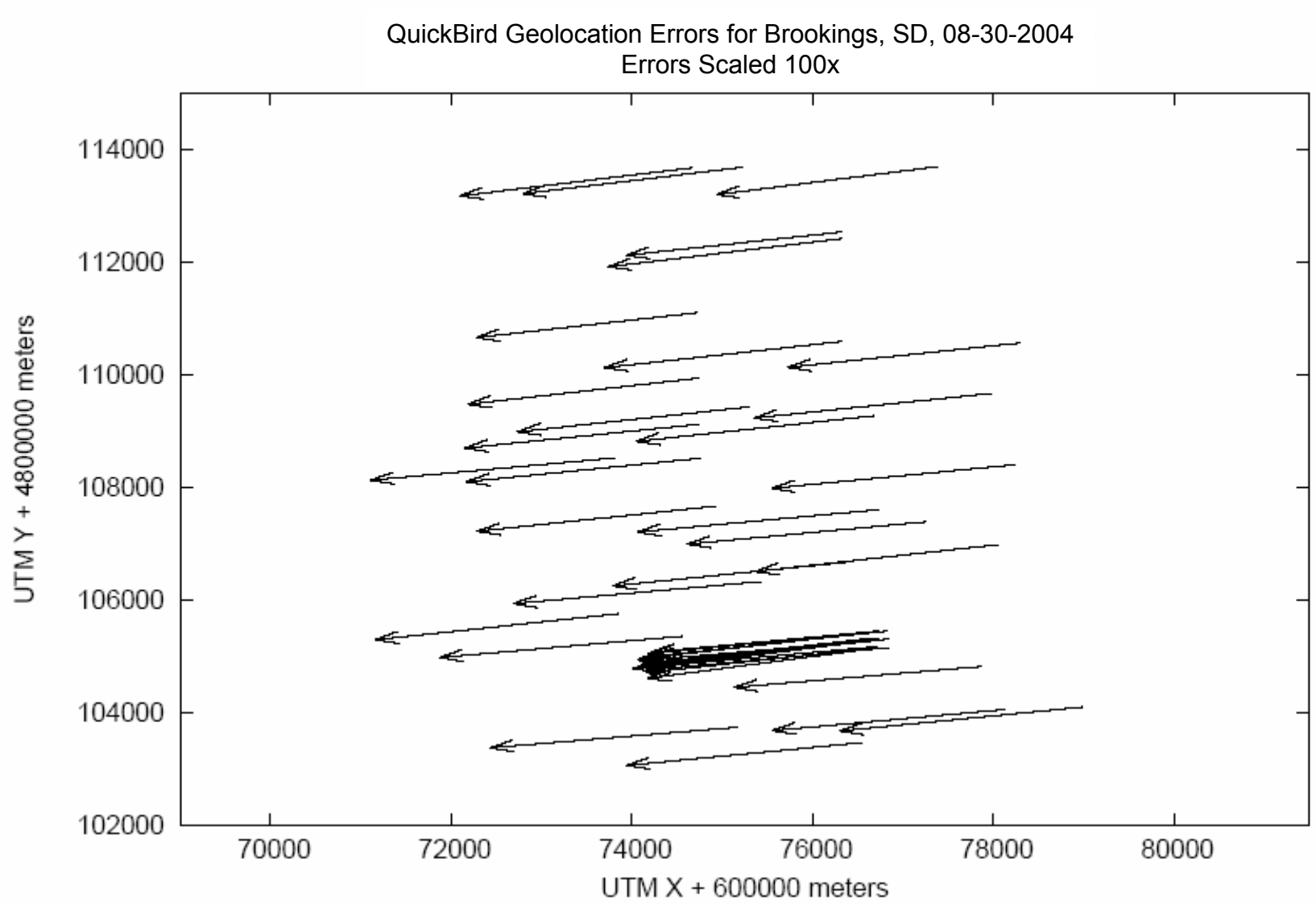


JACIE 2006 Analysis

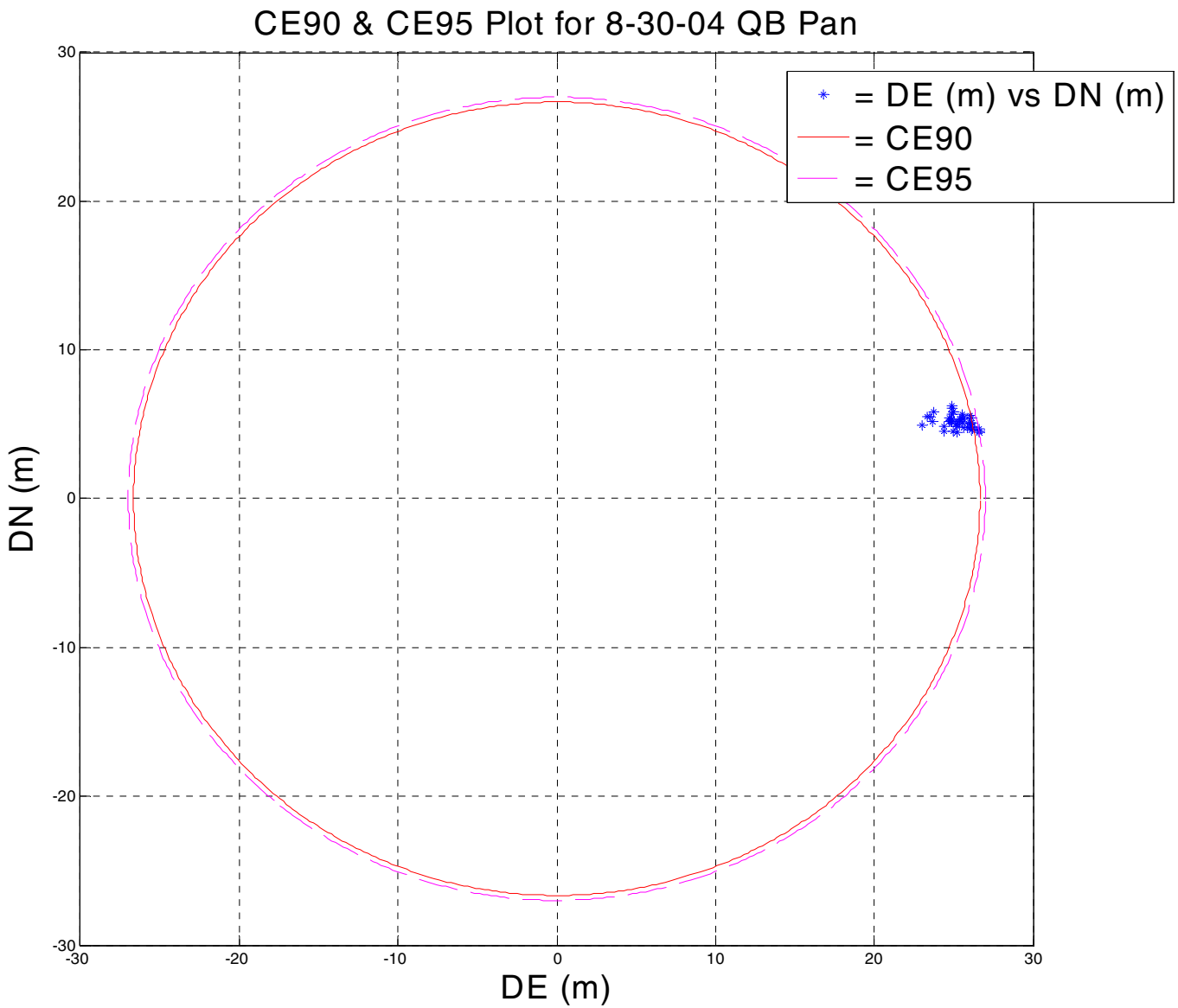


For *Standard* images characterized, the bias generally continued to trend toward the west. However, the two acquisitions with the largest error ran against this trend.

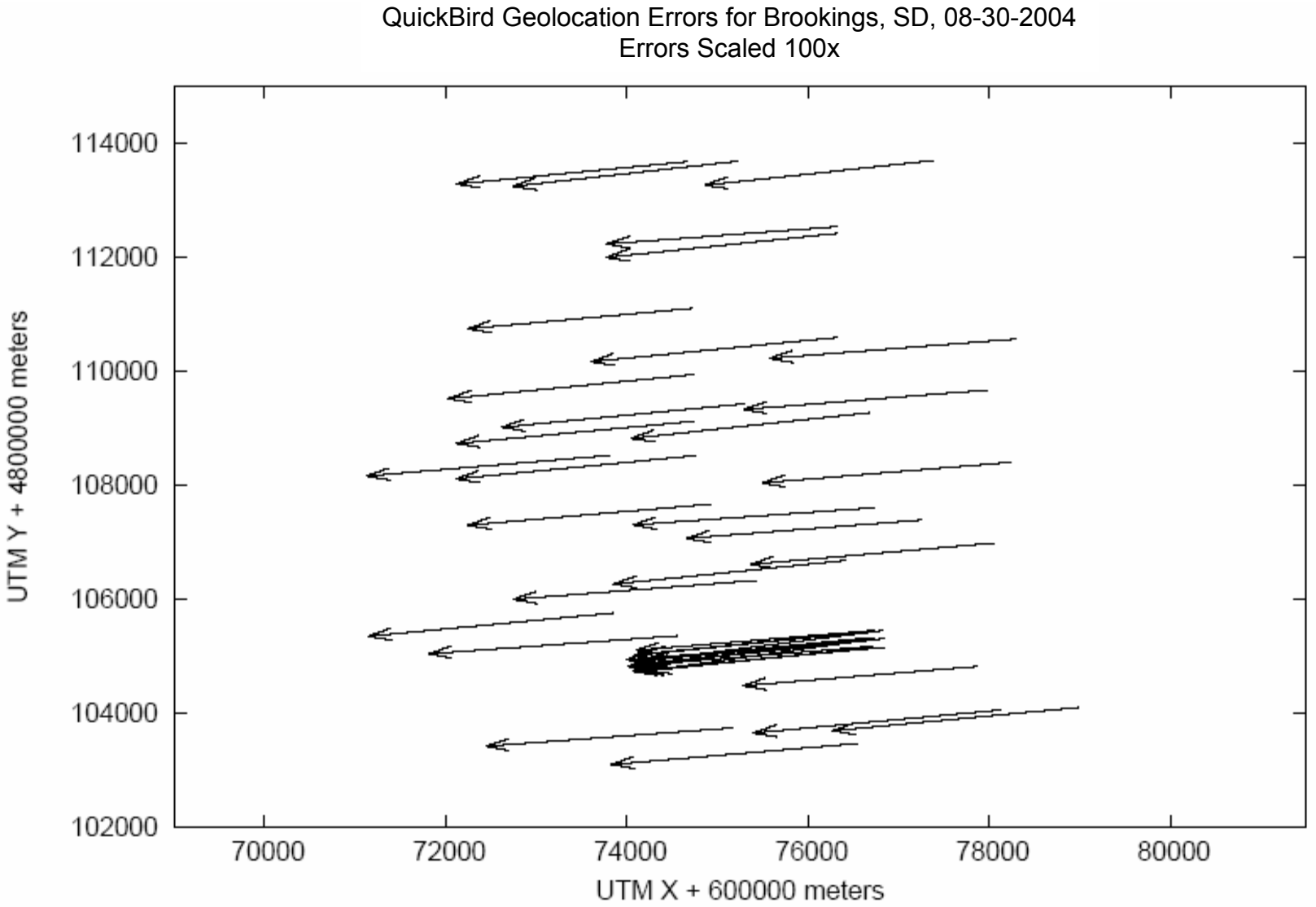
QuickBird 8-30-2004 Panchromatic Band



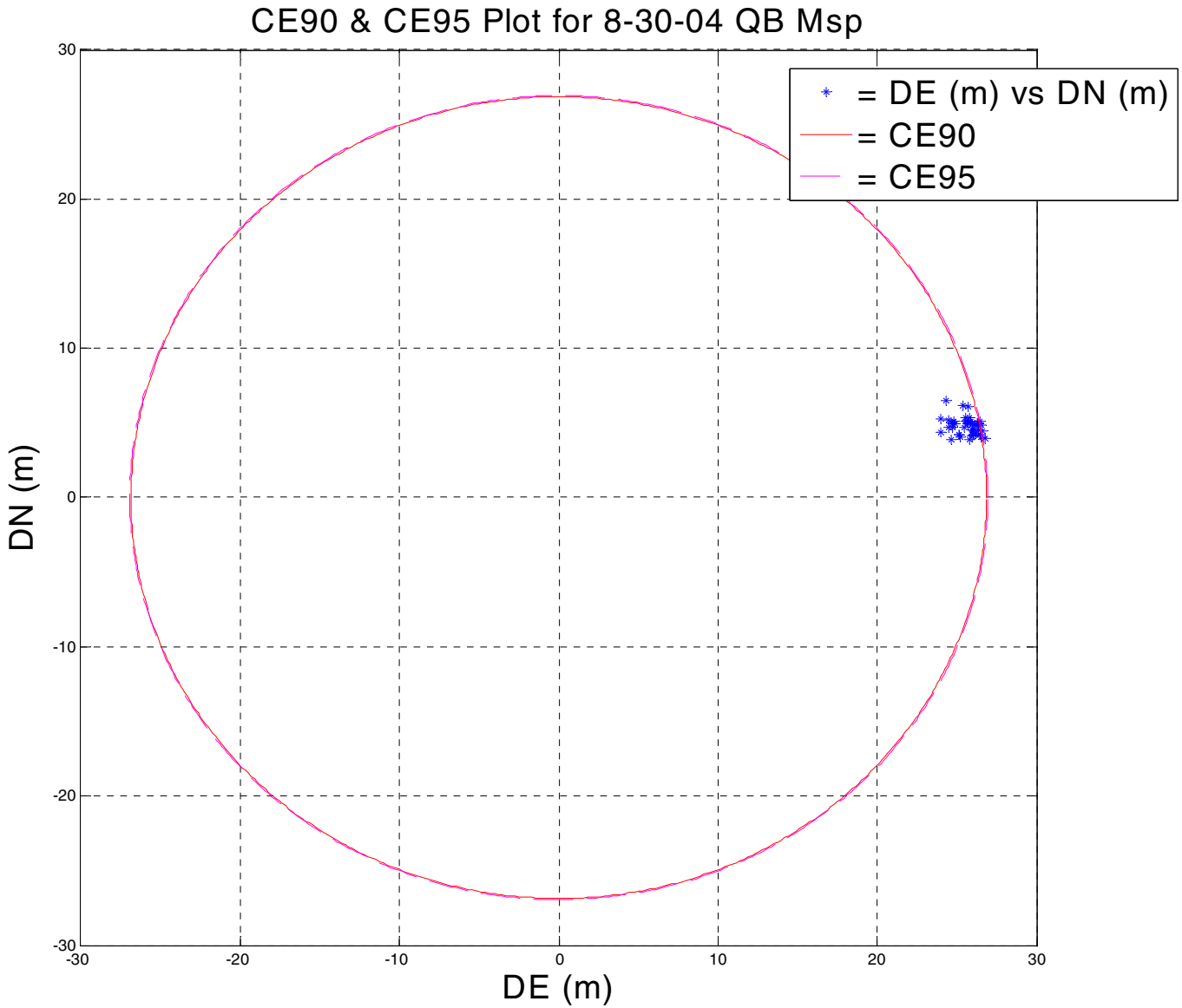
QuickBird 8-30-2004 Panchromatic Band (CE90 = 26.6623 m & CE95 = 26.9906 m)



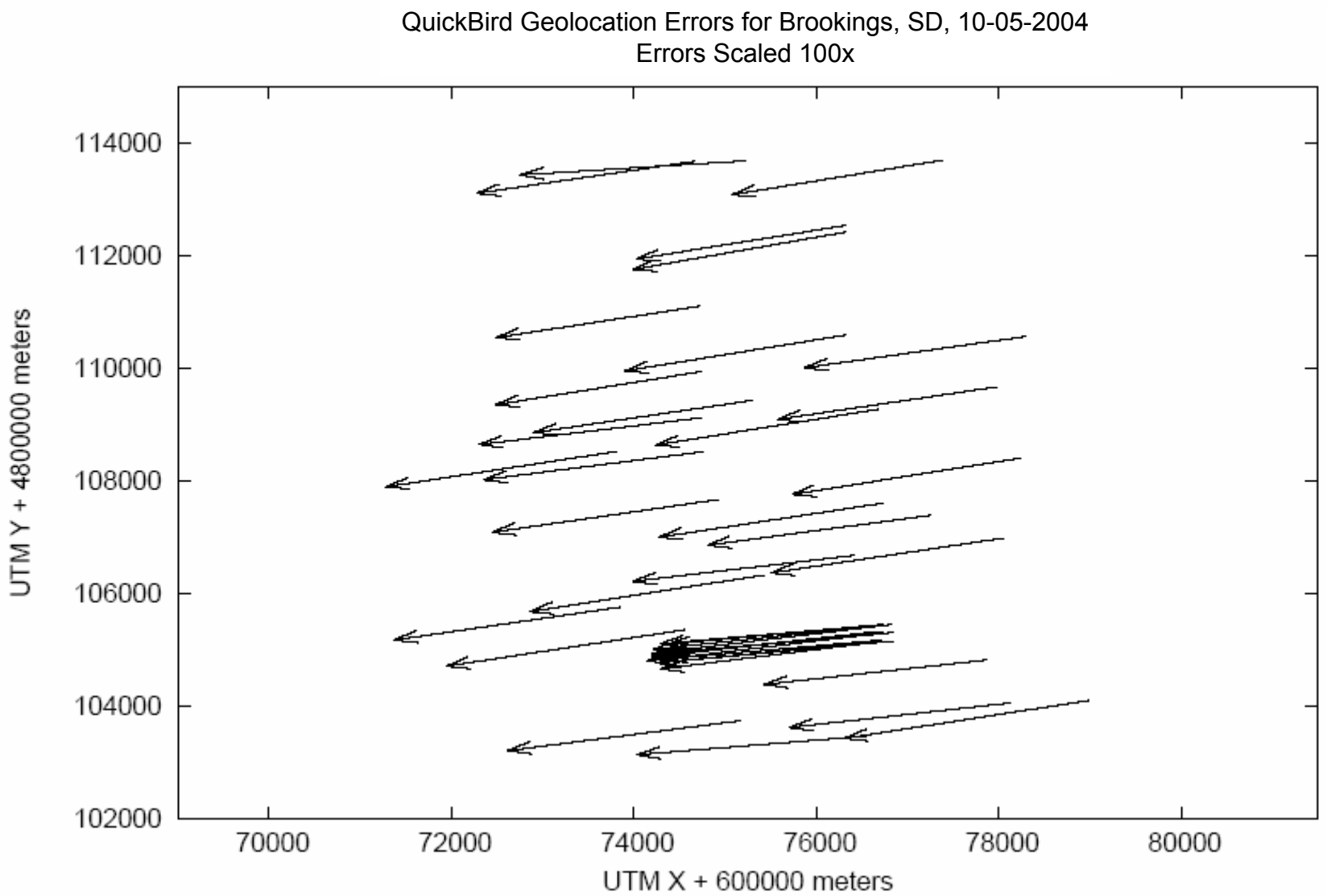
QuickBird 8-30-2004 Multispectral Band



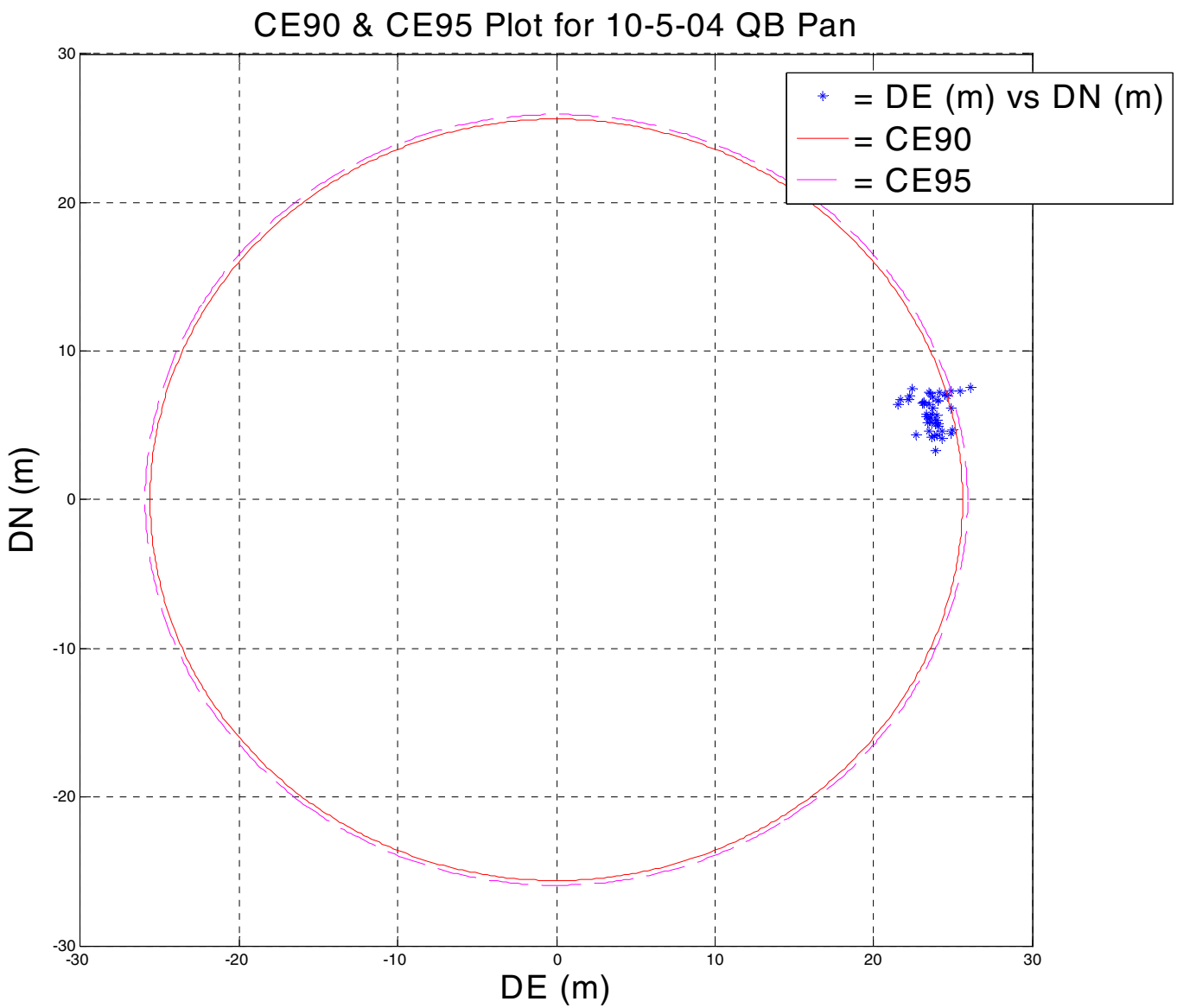
QuickBird 8-30-2004 Multispectral Band (CE90 = 26.8610 m & CE95 = 26.9368 m)



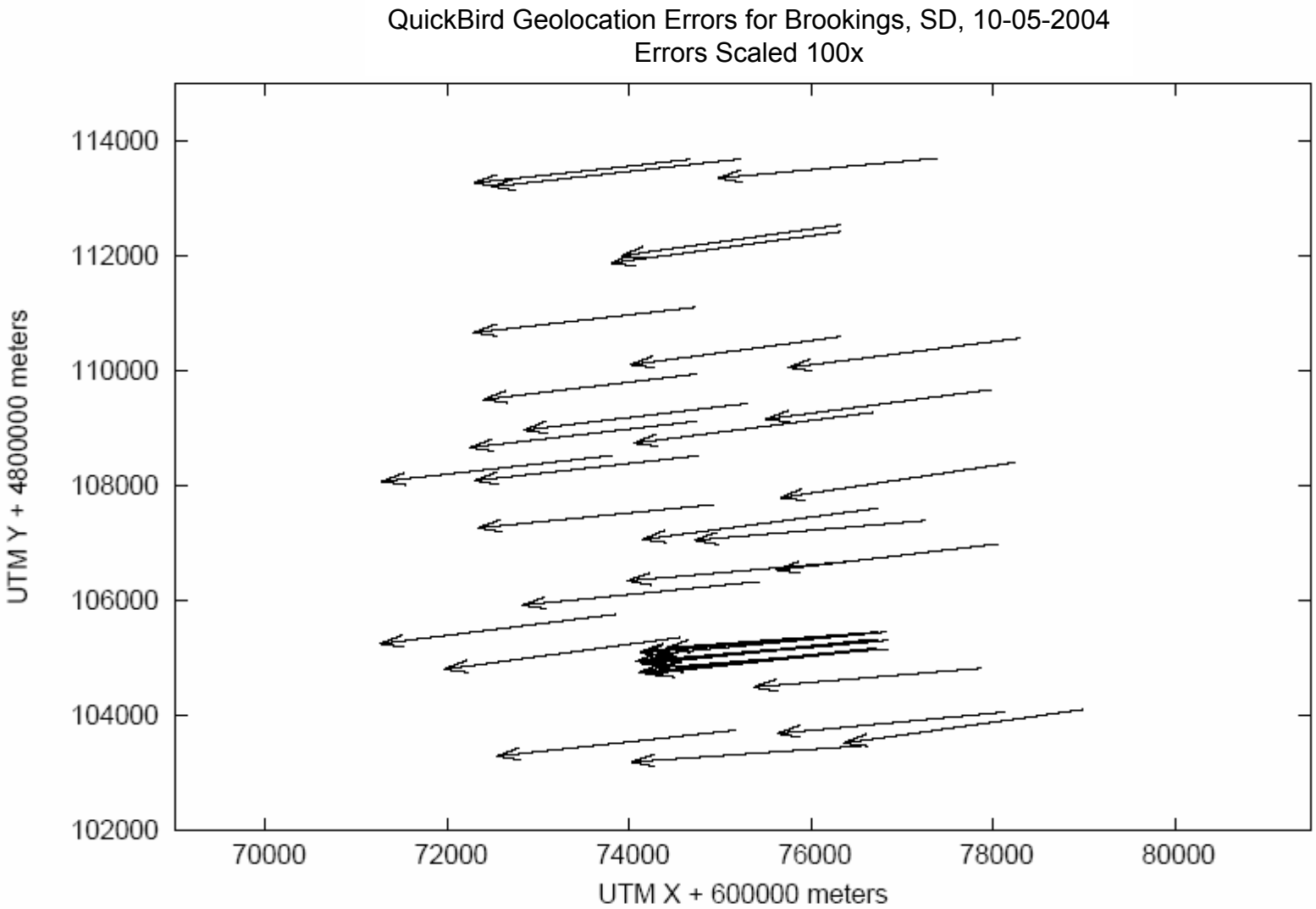
QuickBird 10-5-2004 Panchromatic Band



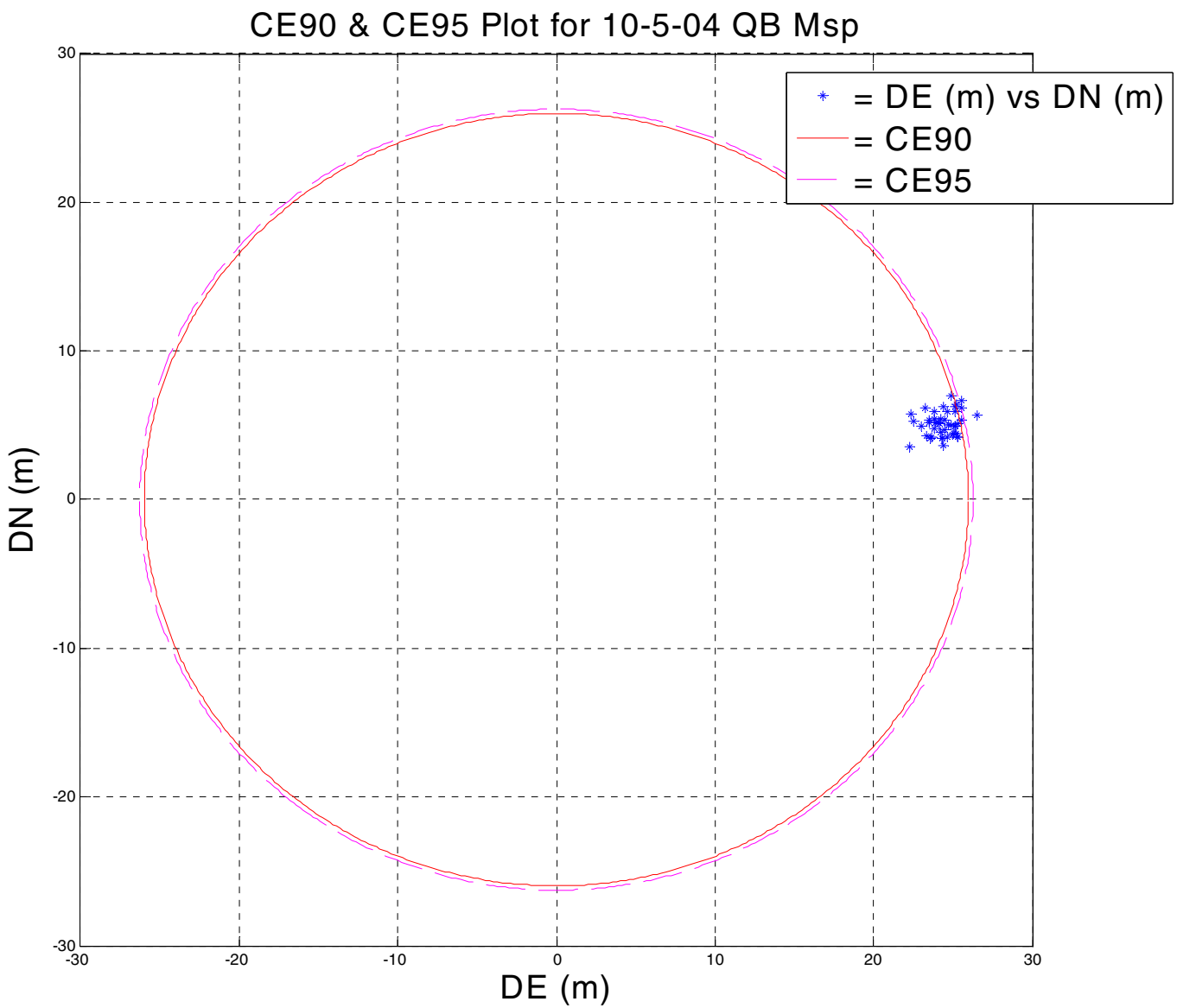
QuickBird 10-5-2004 Panchromatic Band (CE90 = 25.6153 m & CE95 = 25.9286 m)



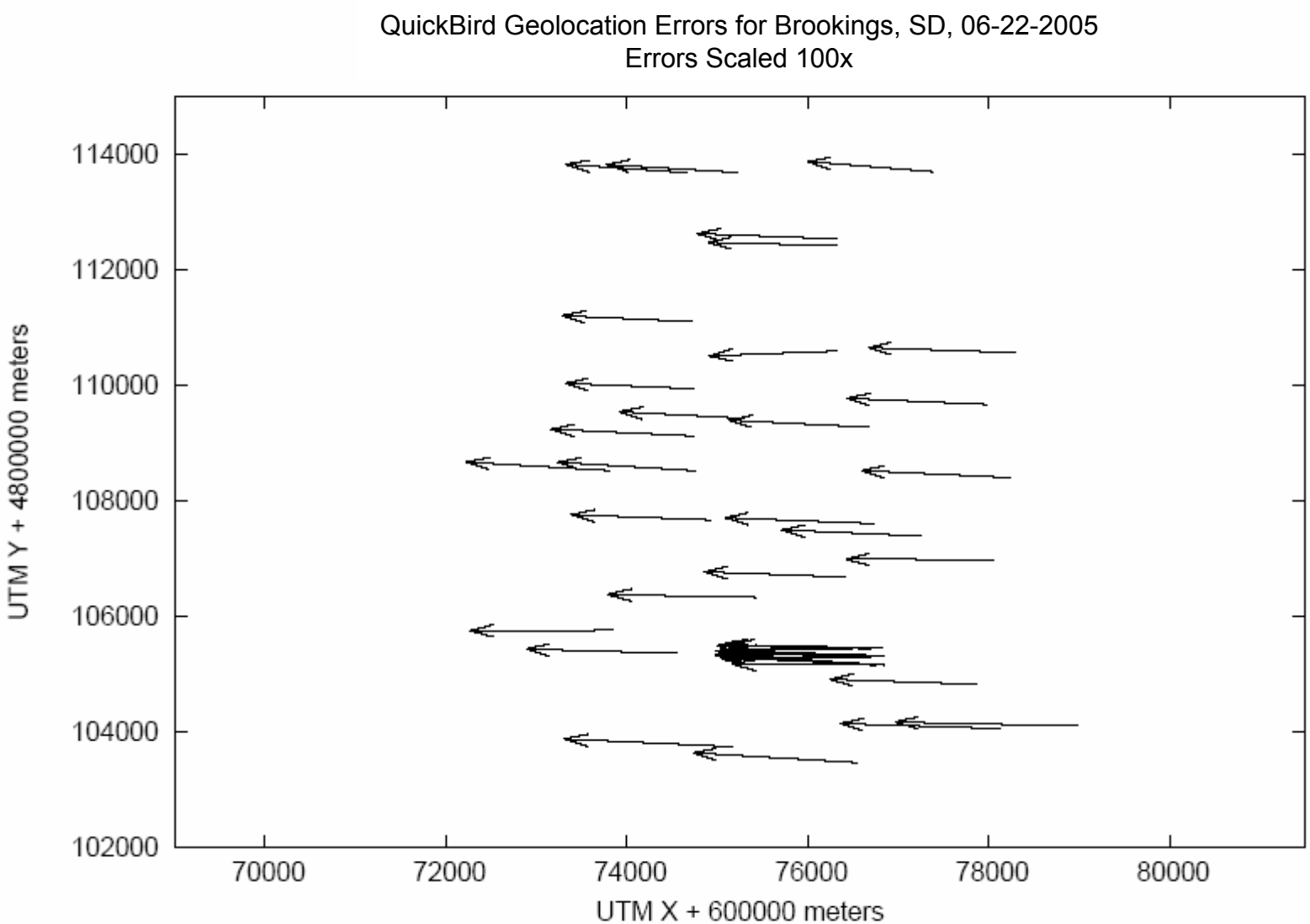
QuickBird 10-5-2004 Multispectral Band



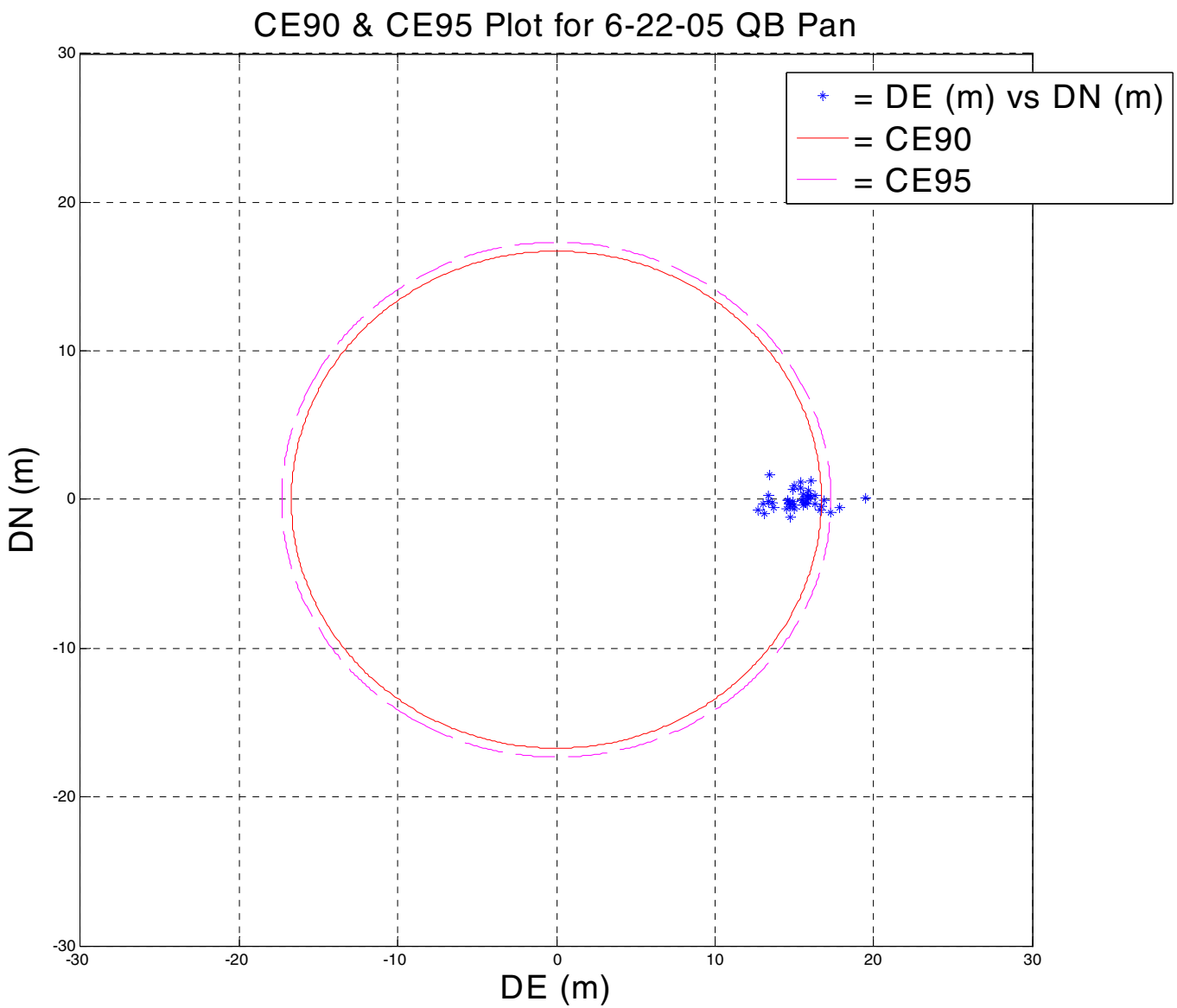
QuickBird 10-5-2004 Multispectral Band (CE90 = 25.9796 m & CE95 = 26.2656 m)



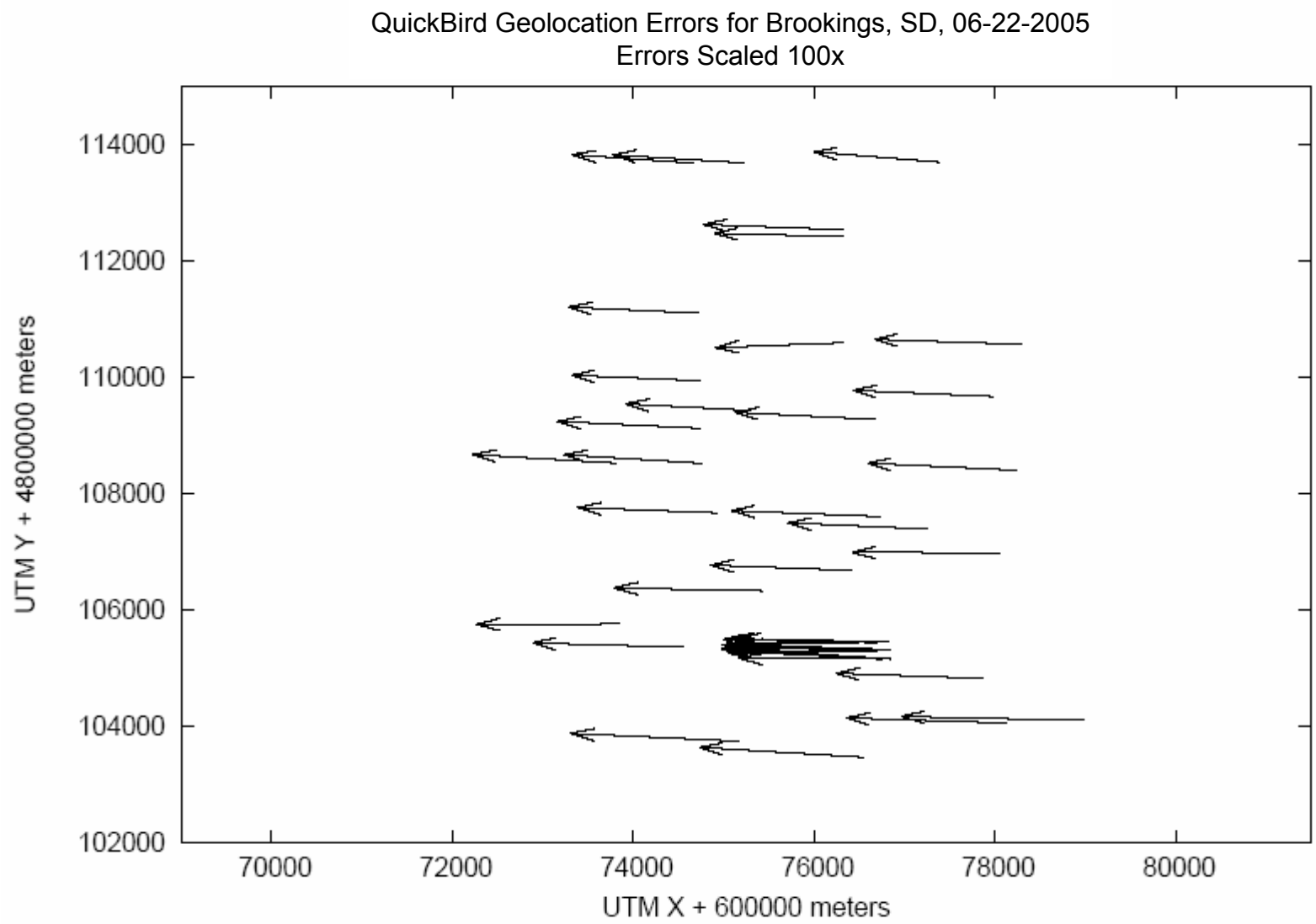
QuickBird 6-22-2005 Panchromatic Band



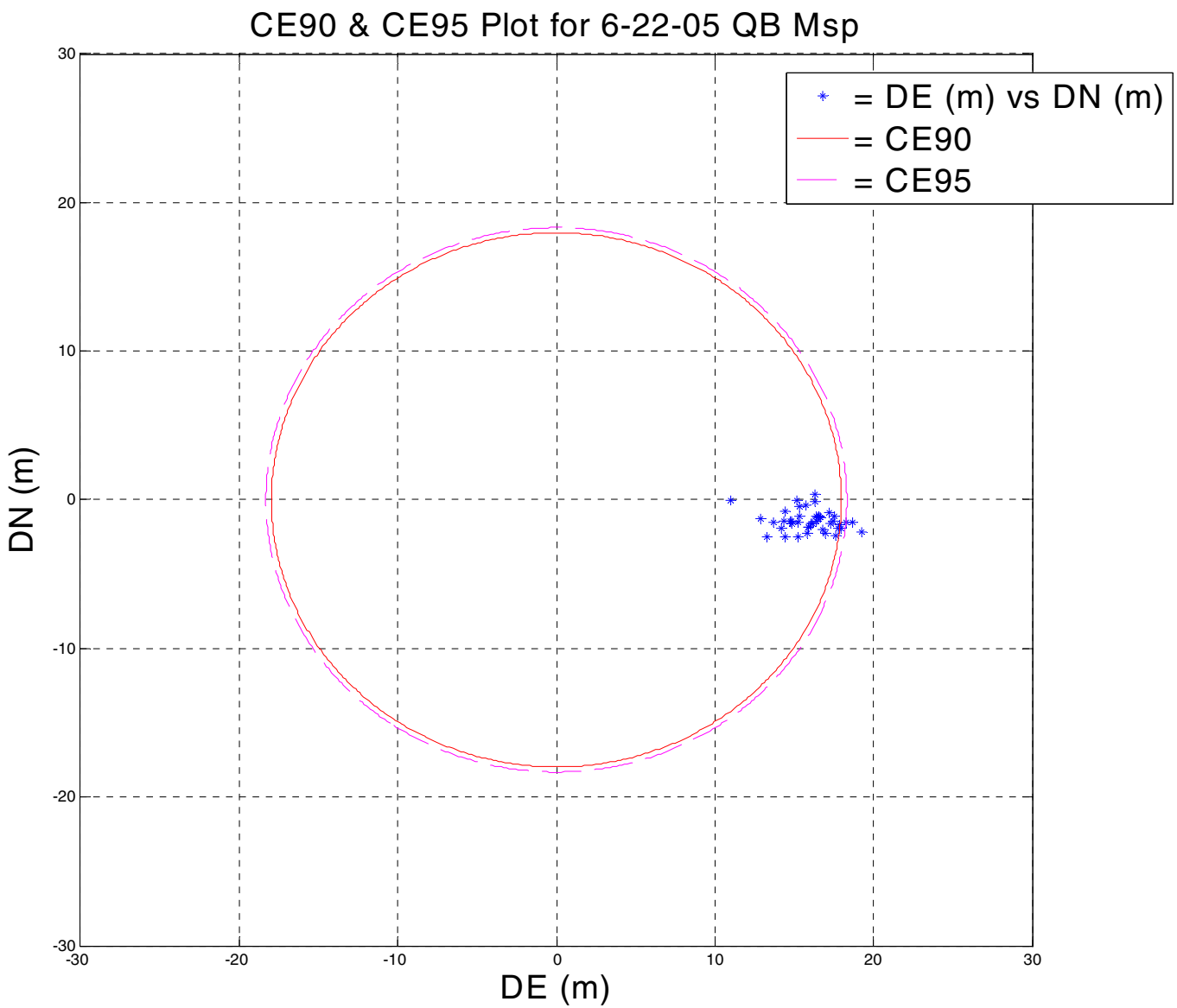
QuickBird 6-22-2005 Panchromatic Band (CE90 = 16.7135 m & CE95 = 17.3145 m)



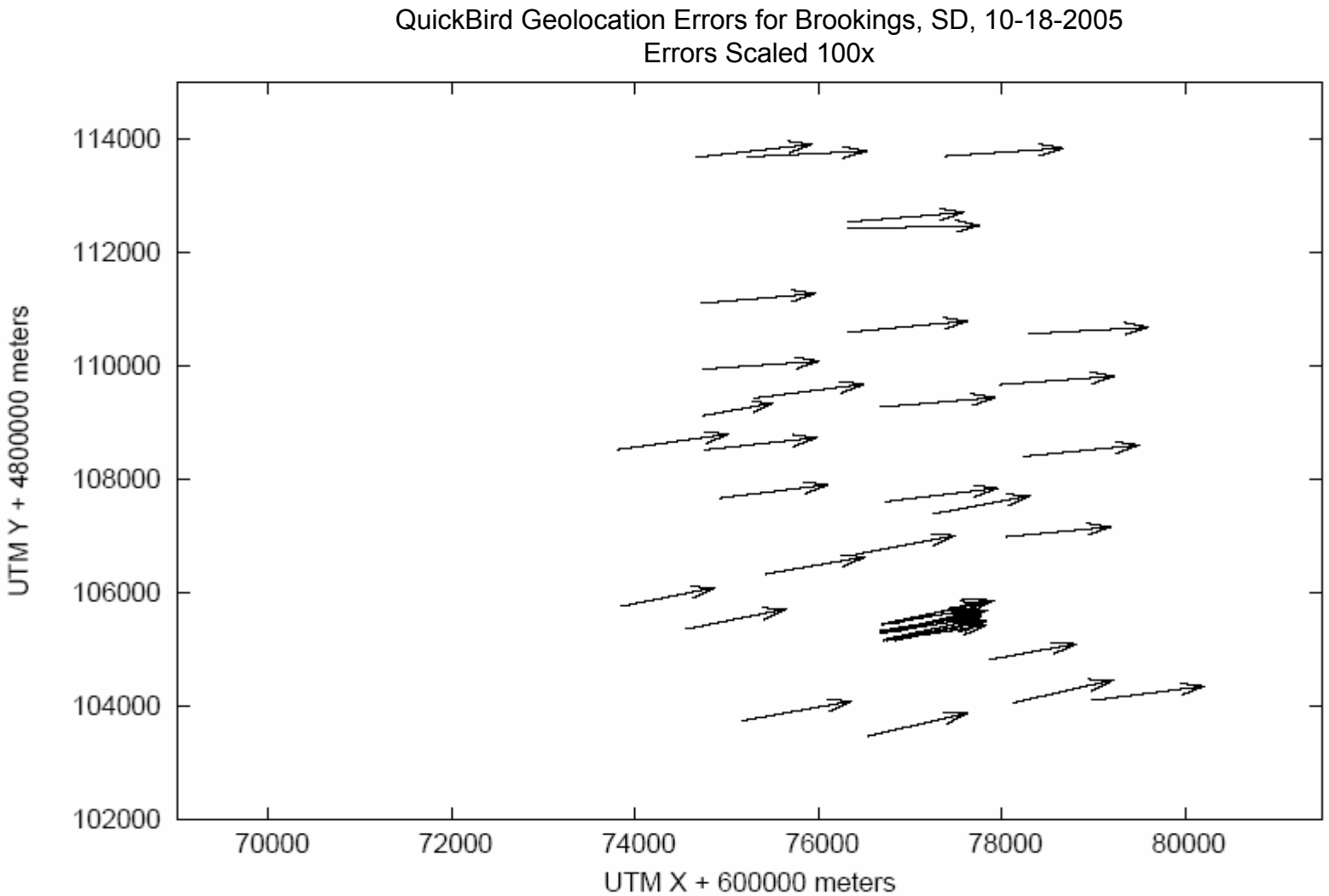
QuickBird 6-22-2005 Multispectral Band



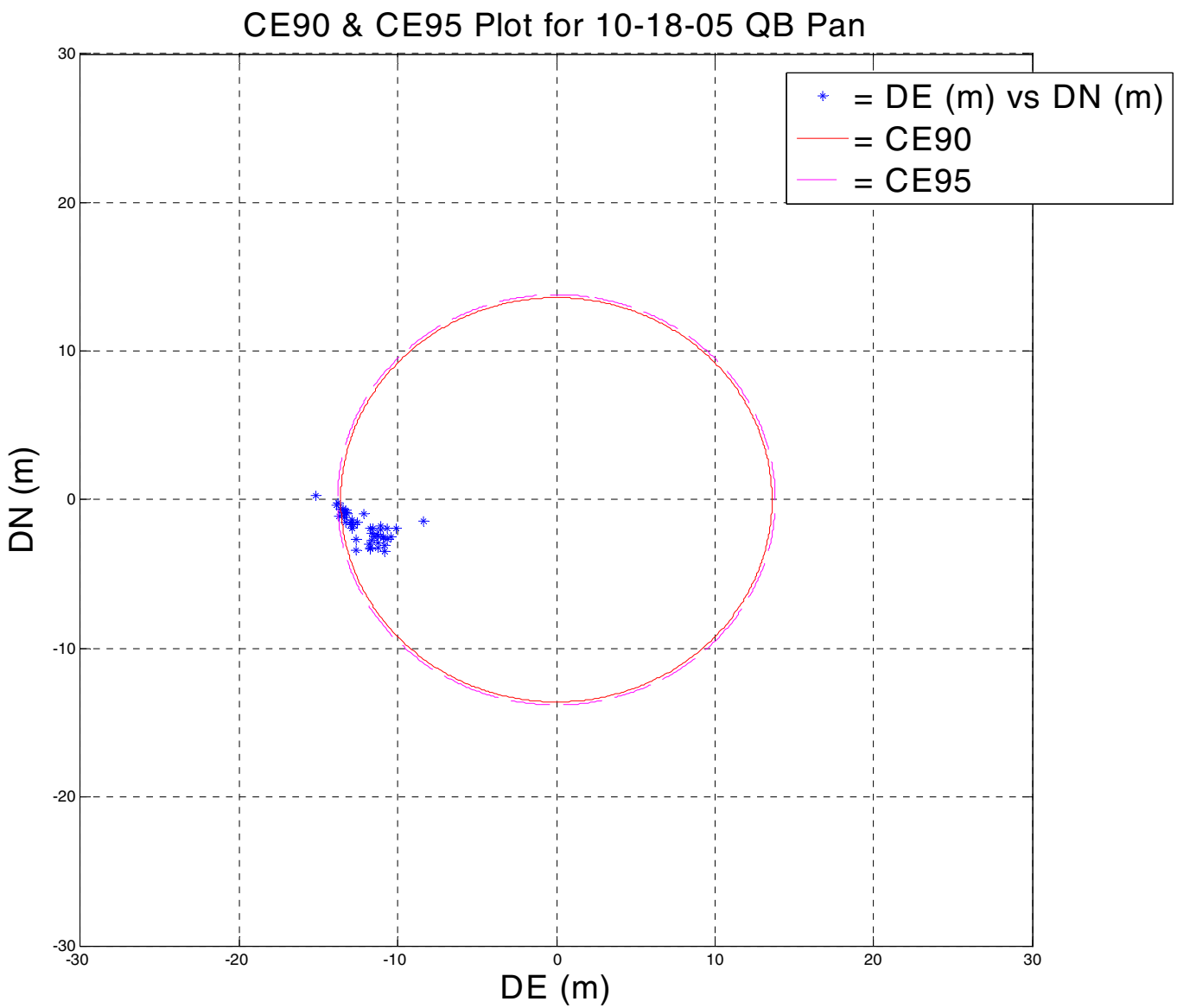
QuickBird 6-22-2005 Multispectral Band (CE90 = 17.9719 m & CE95 = 18.3163 m)



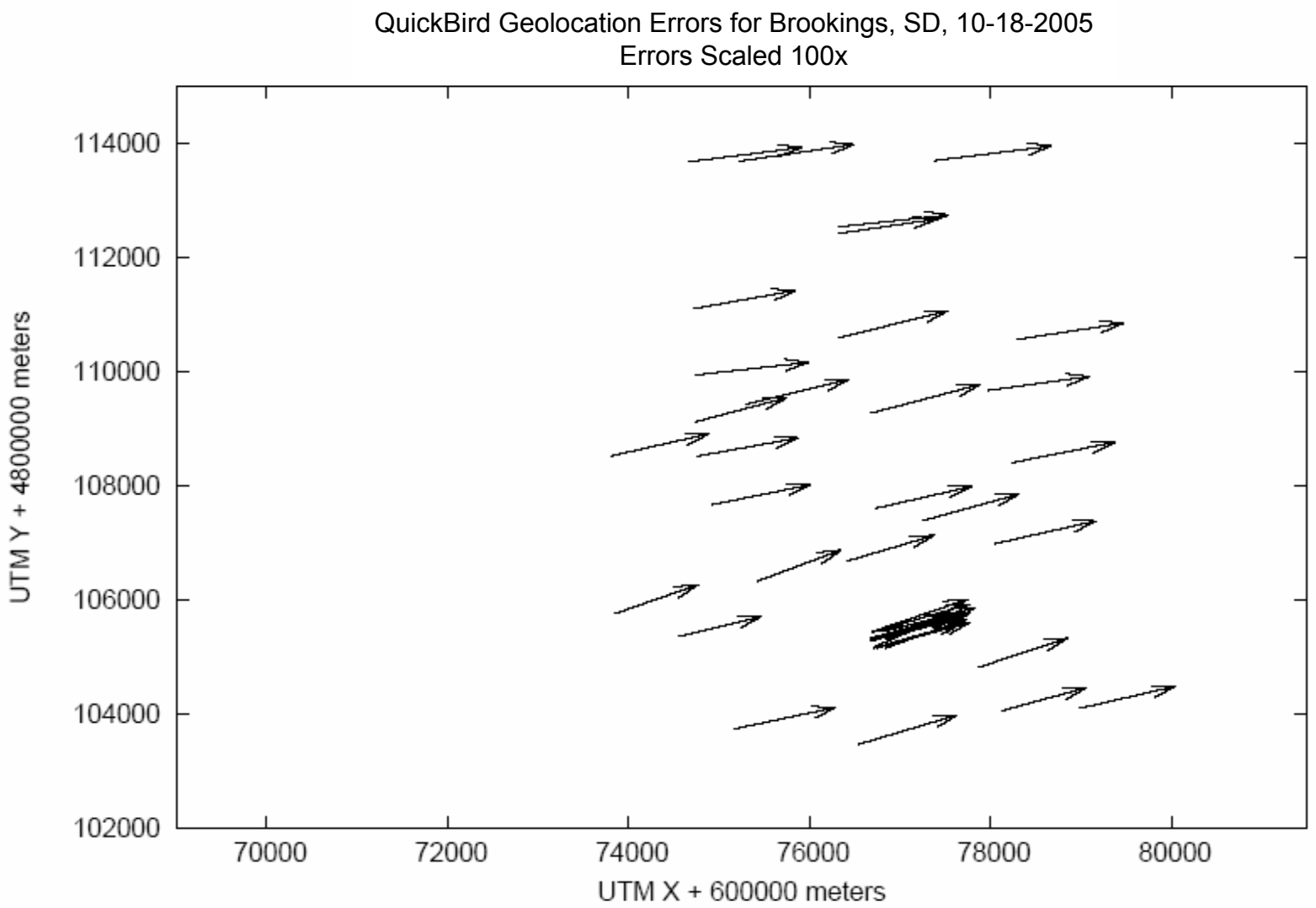
QuickBird 10-18-2005 Panchromatic Band



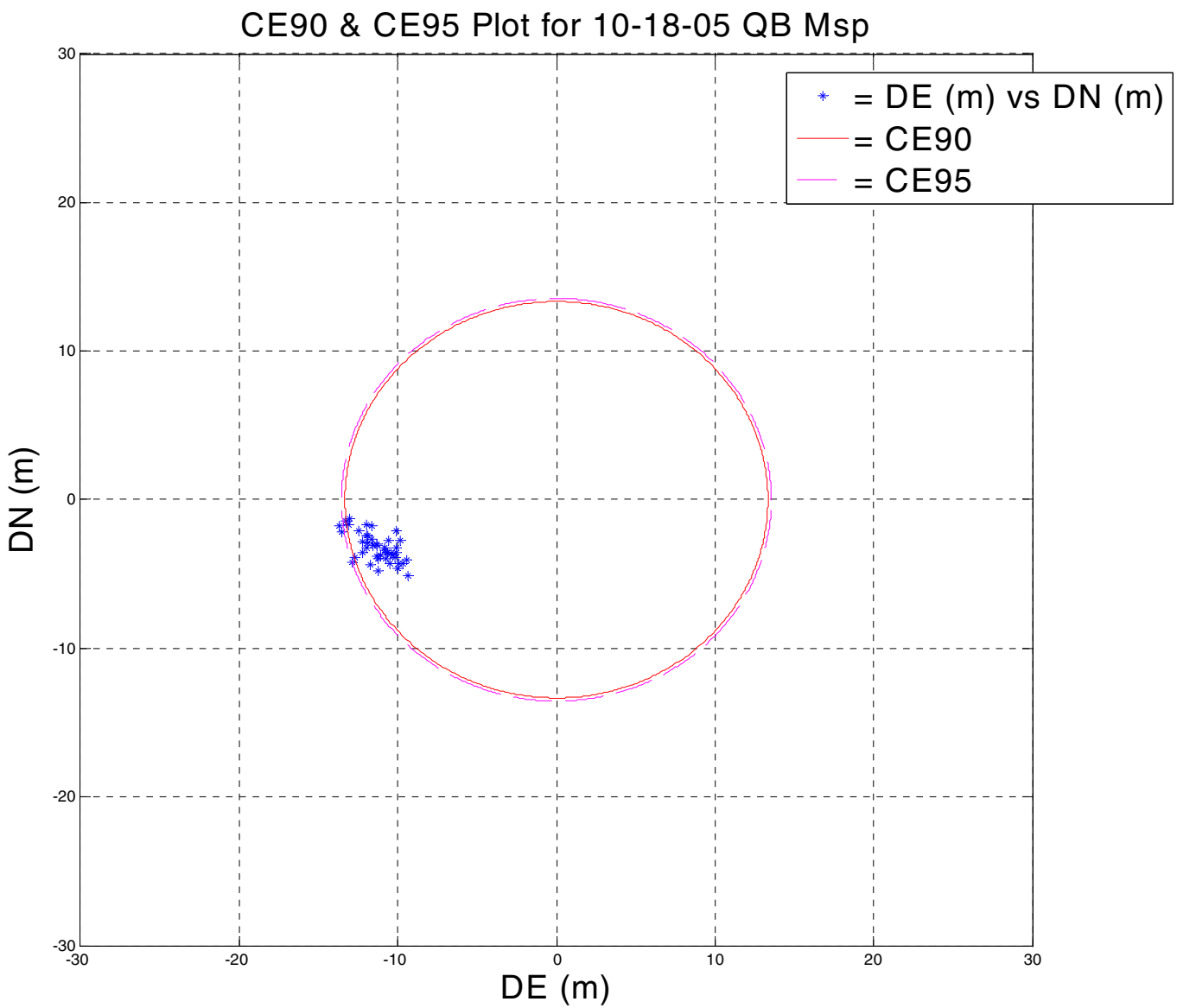
QuickBird 10-18-2005 Panchromatic Band (CE90 = 13.5985 m & CE95 = 13.8037 m)



QuickBird 10-18-2005 Multispectral Band



QuickBird 10-18-2005 Multispectral Band (CE90 = 13.3361 m & CE95 = 13.5476 m)

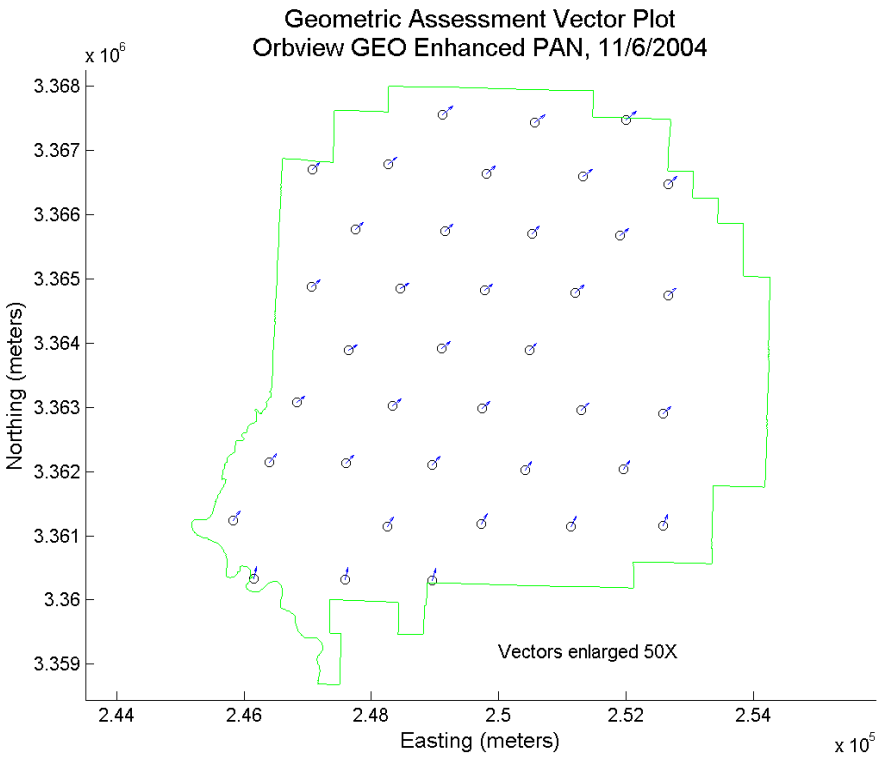


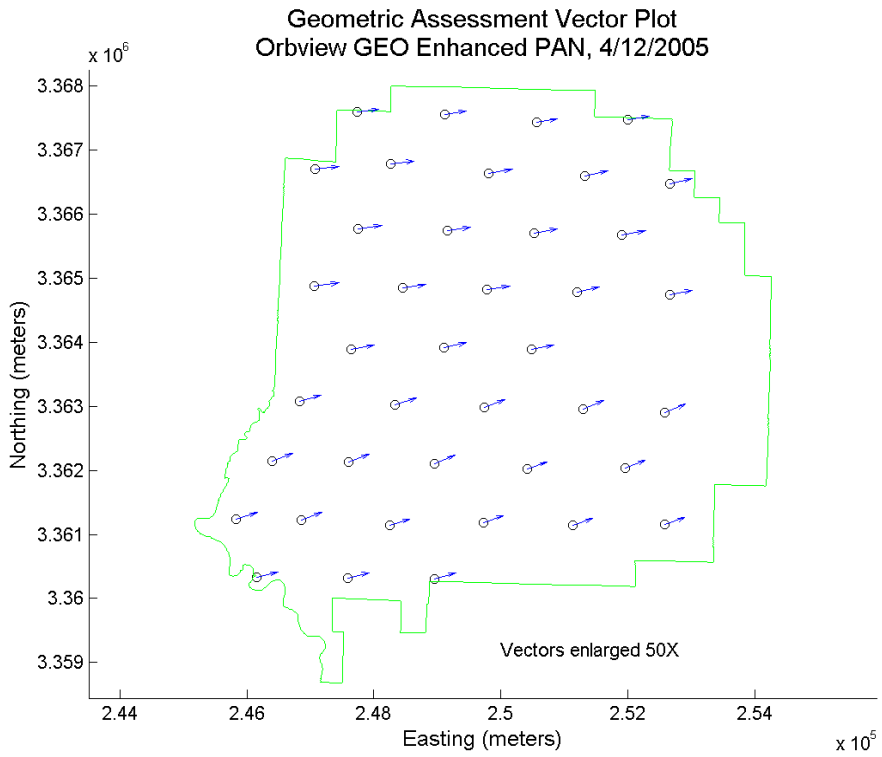
SSC – OrbView-3 *GEO Enhanced* PAN

Stennis Space Center

6 NOV 2004	
CE_{90}:	3.88 m
CE_{95}:	4.05 m
Circular Standard Error:	0.55 m

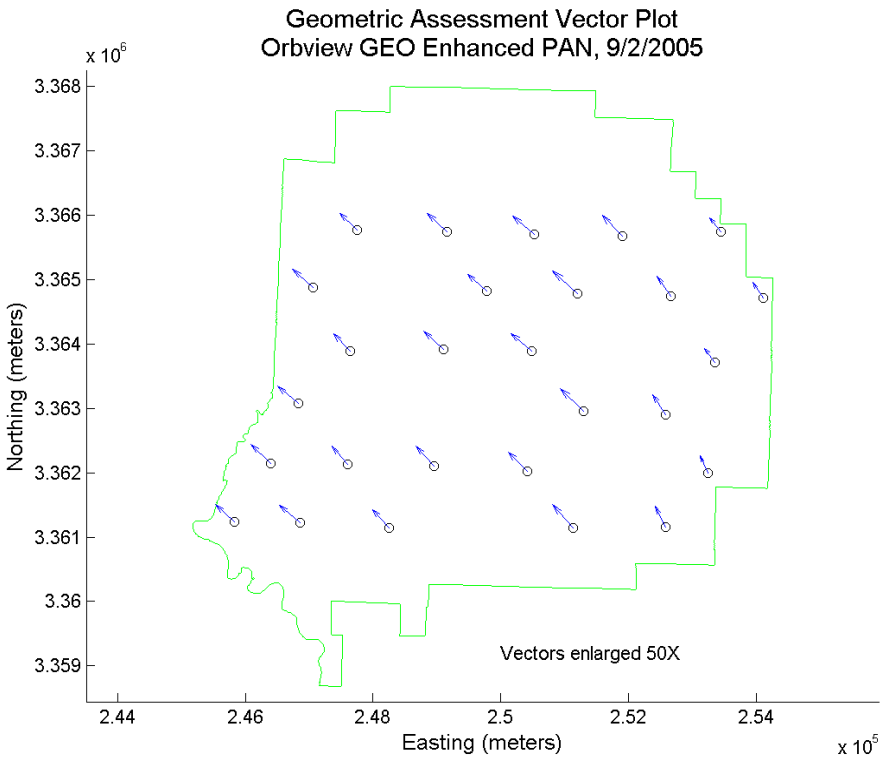
12 APR 2005	
CE_{90}:	7.52 m
CE_{95}:	7.65 m
Circular Standard Error:	0.50 m



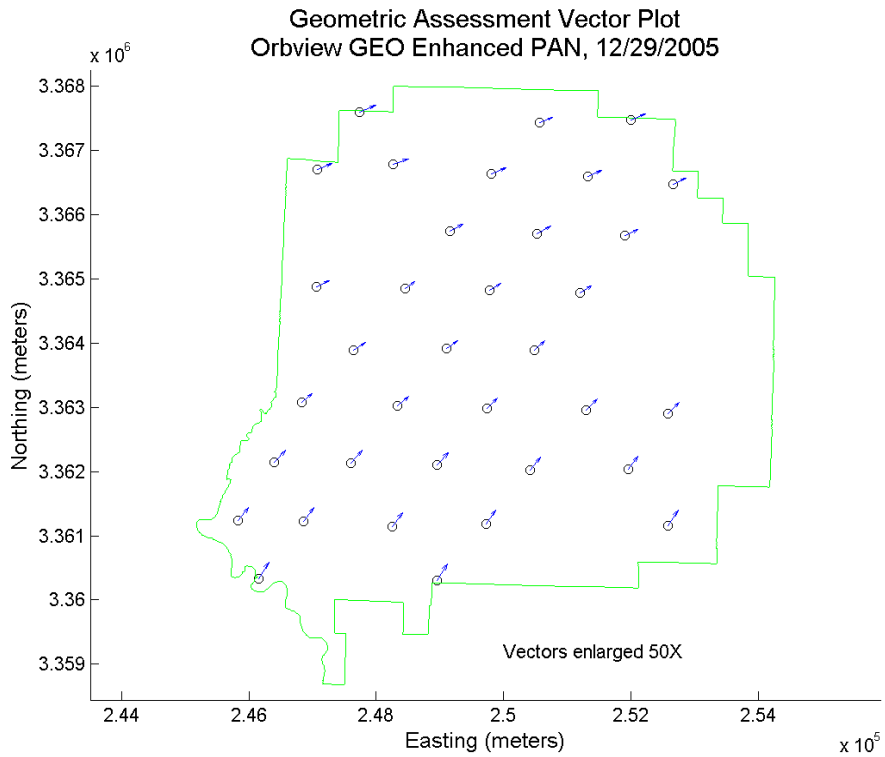


SSC – OrbView-3 *GEO Enhanced* PAN

2 SEP 2005	
CE_{90}:	9.79 m
CE_{95}:	10.11 m
Circular Standard Error:	1.04 m



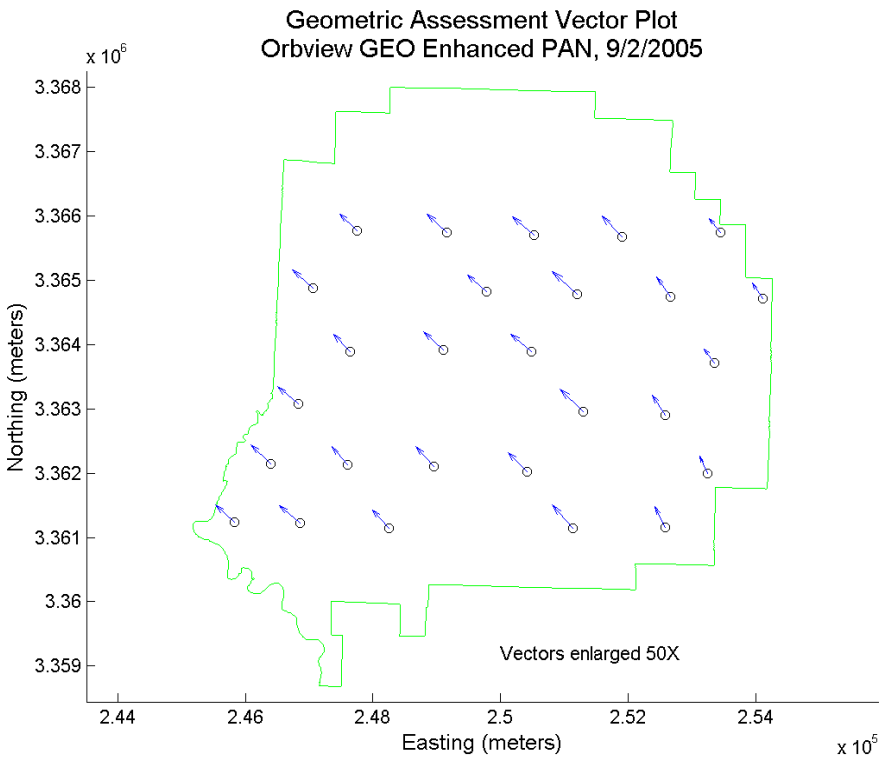
29 DEC 2005	
CE_{90}:	5.53 m
CE_{95}:	5.98 m
Circular Standard Error:	0.82 m



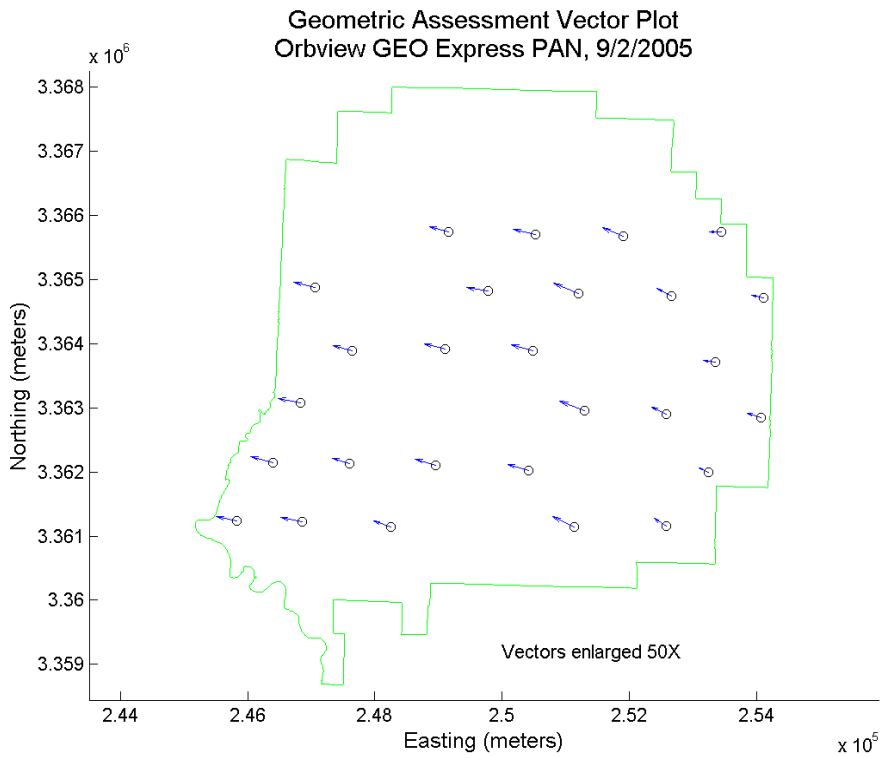
SSC – OrbView-3 *GEO Express* PAN

Stennis Space Center

2 SEP 2005 (GEO Enhanced)
CE_{90}: 9.79 m
CE_{95}: 10.11 m
Circular Standard Error: 1.04 m

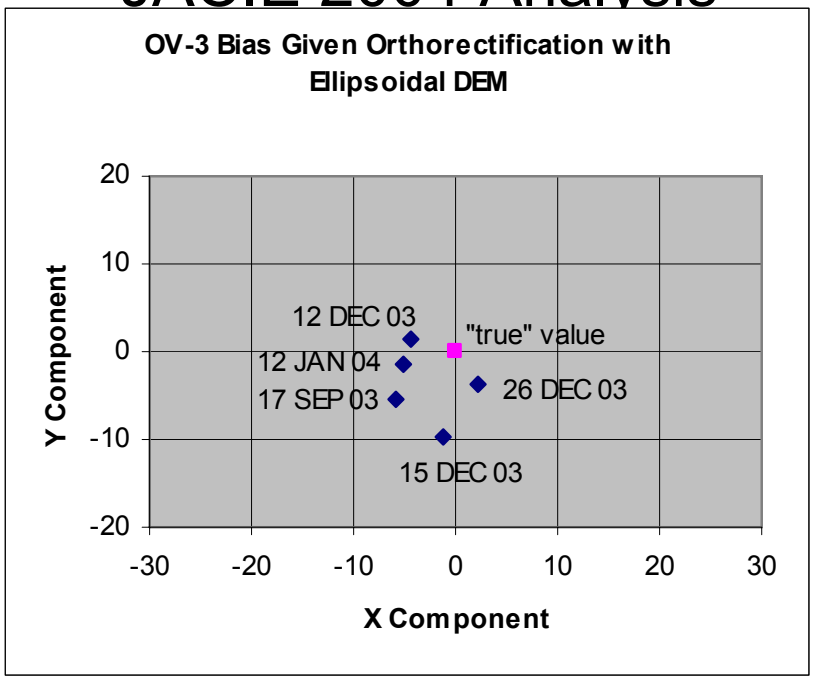


2 SEP 2005 (GEO Express)
CE_{90}: 7.65 m
CE_{95}: 8.35 m
Circular Standard Error: 1.09 m

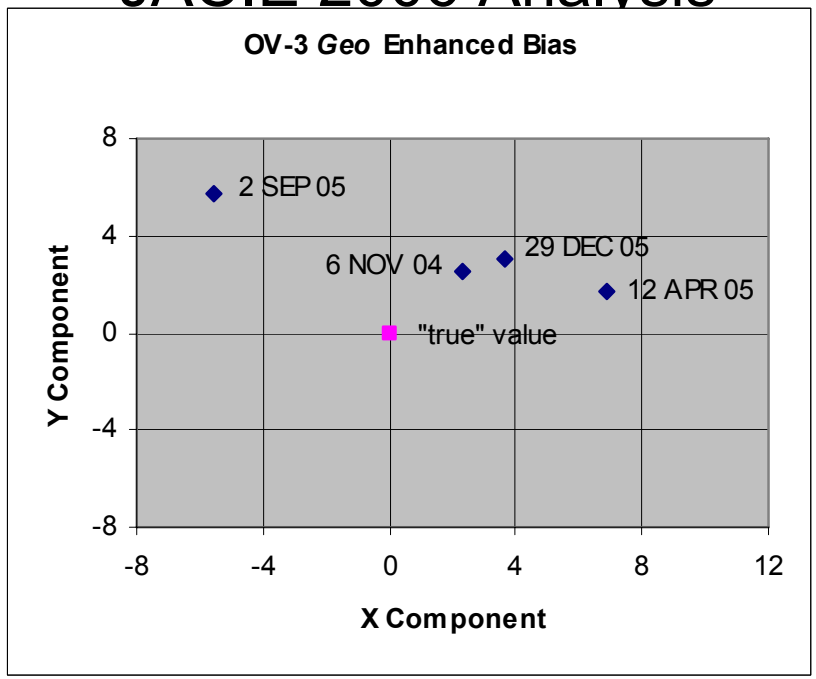


OrbView-3 – No Clear Bias Trend

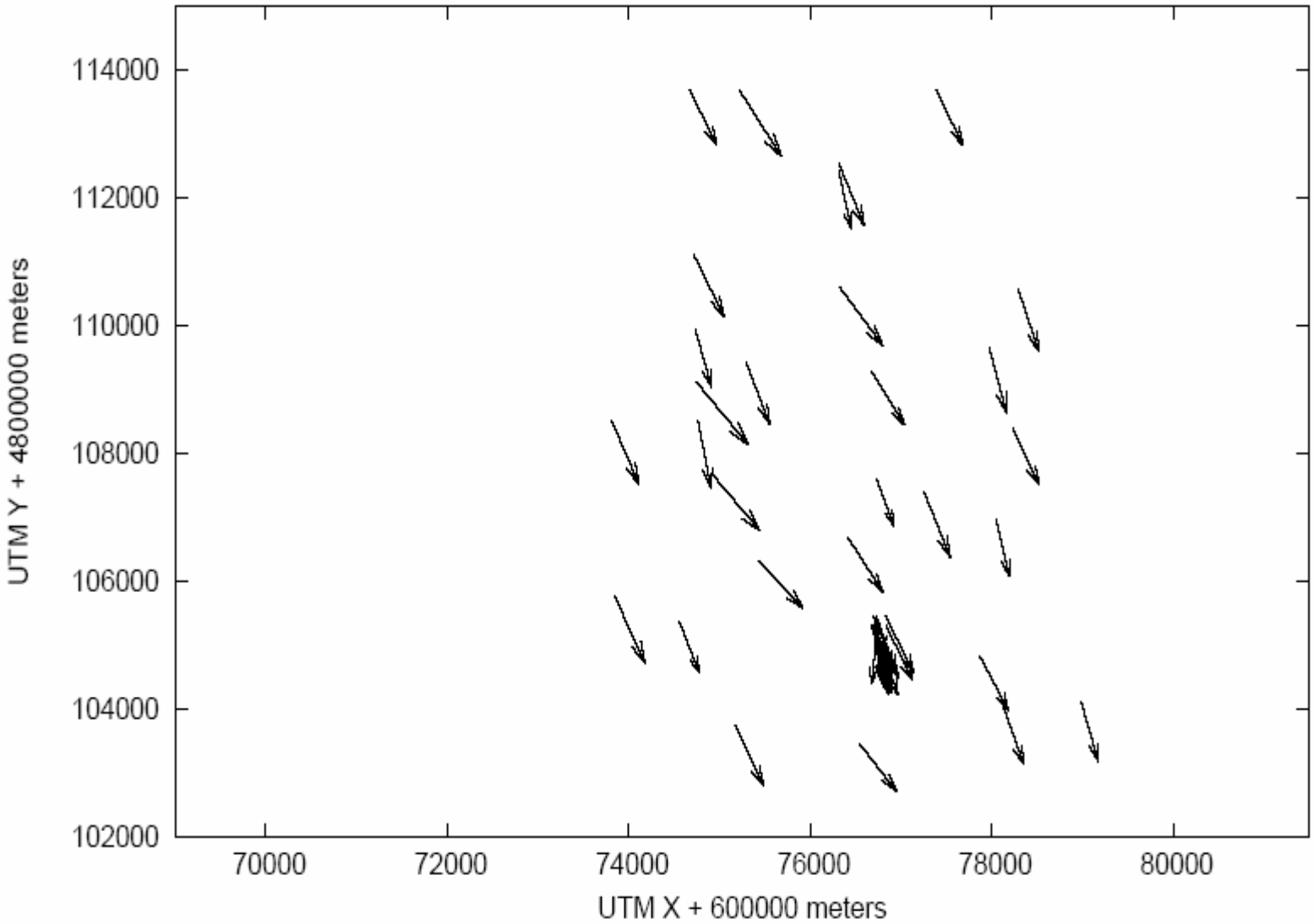
JACIE 2004 Analysis



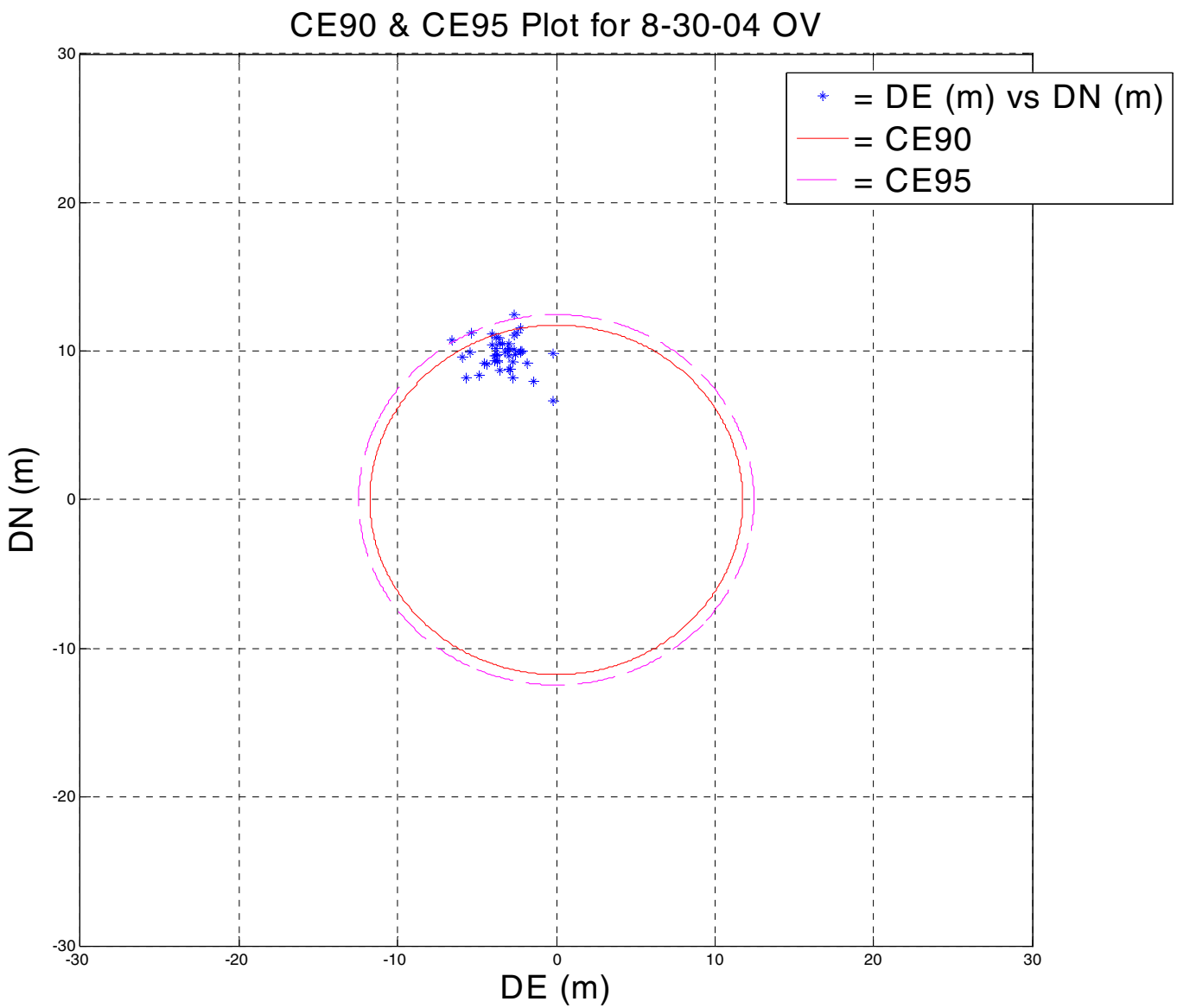
JACIE 2006 Analysis



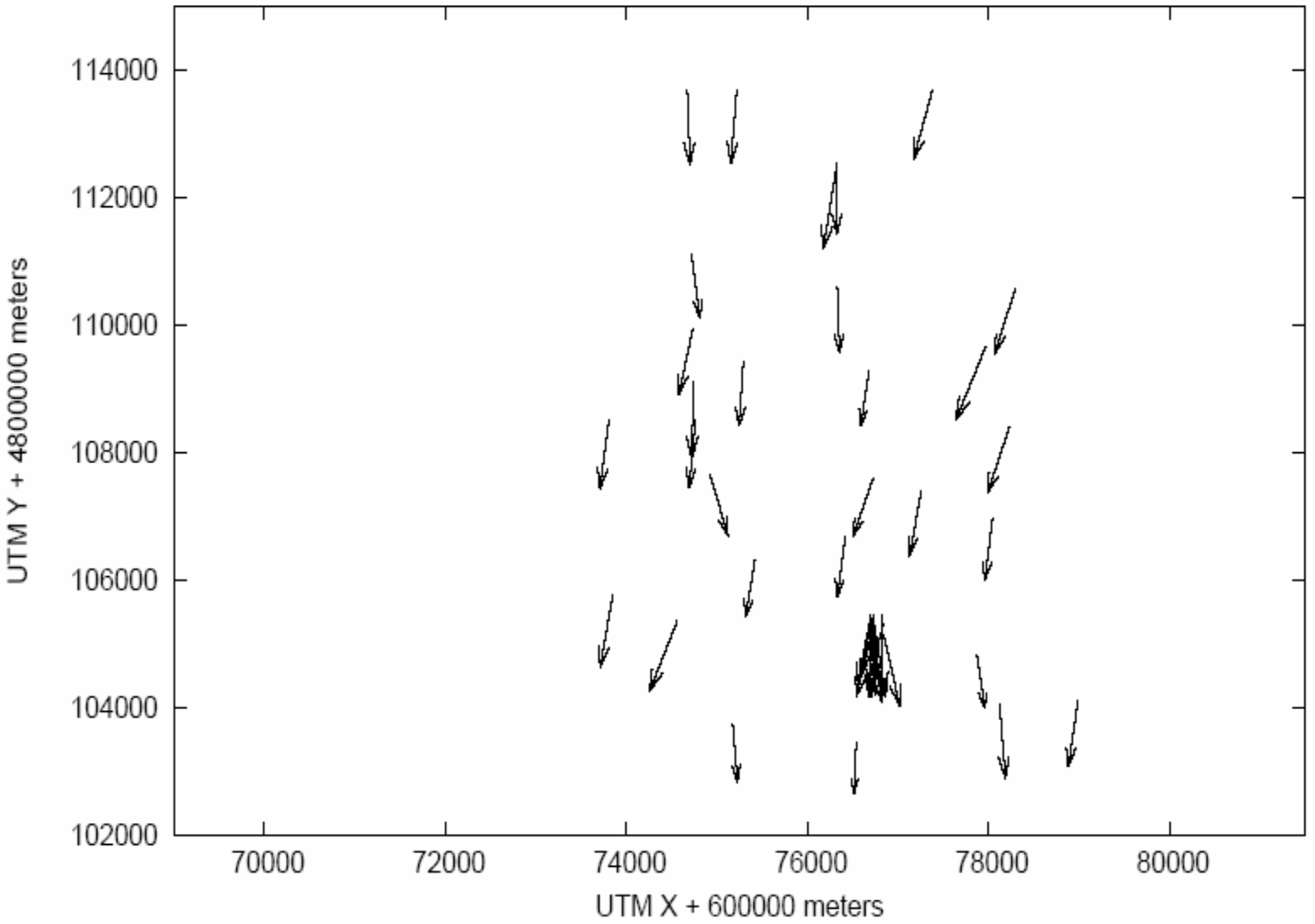
OrbView-3 8-30-2004 Orthorectified



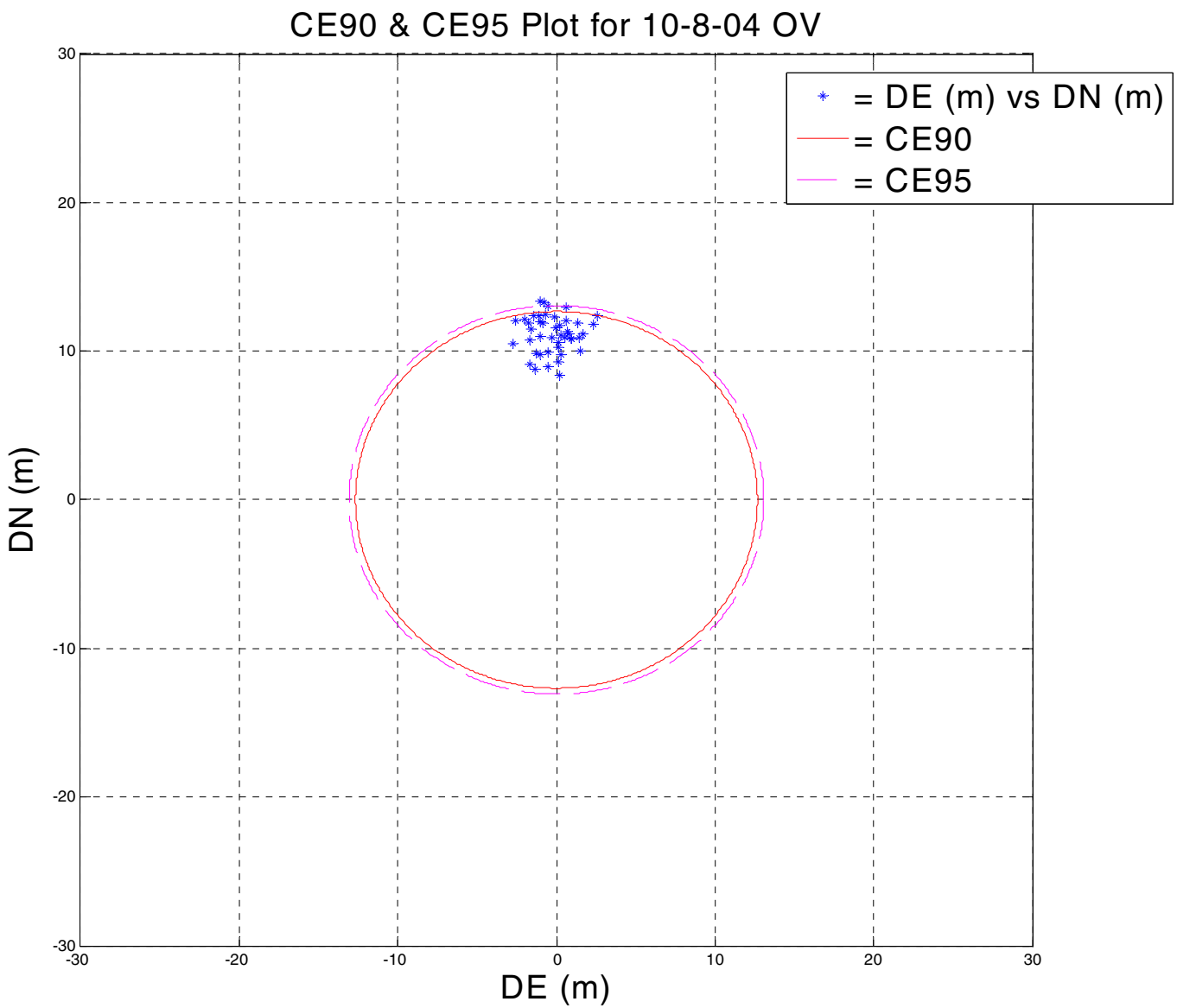
OrbView-3 8-30-2004 Orthorectified (CE90 = 11.7554 m & CE95 = 12.4592 m)



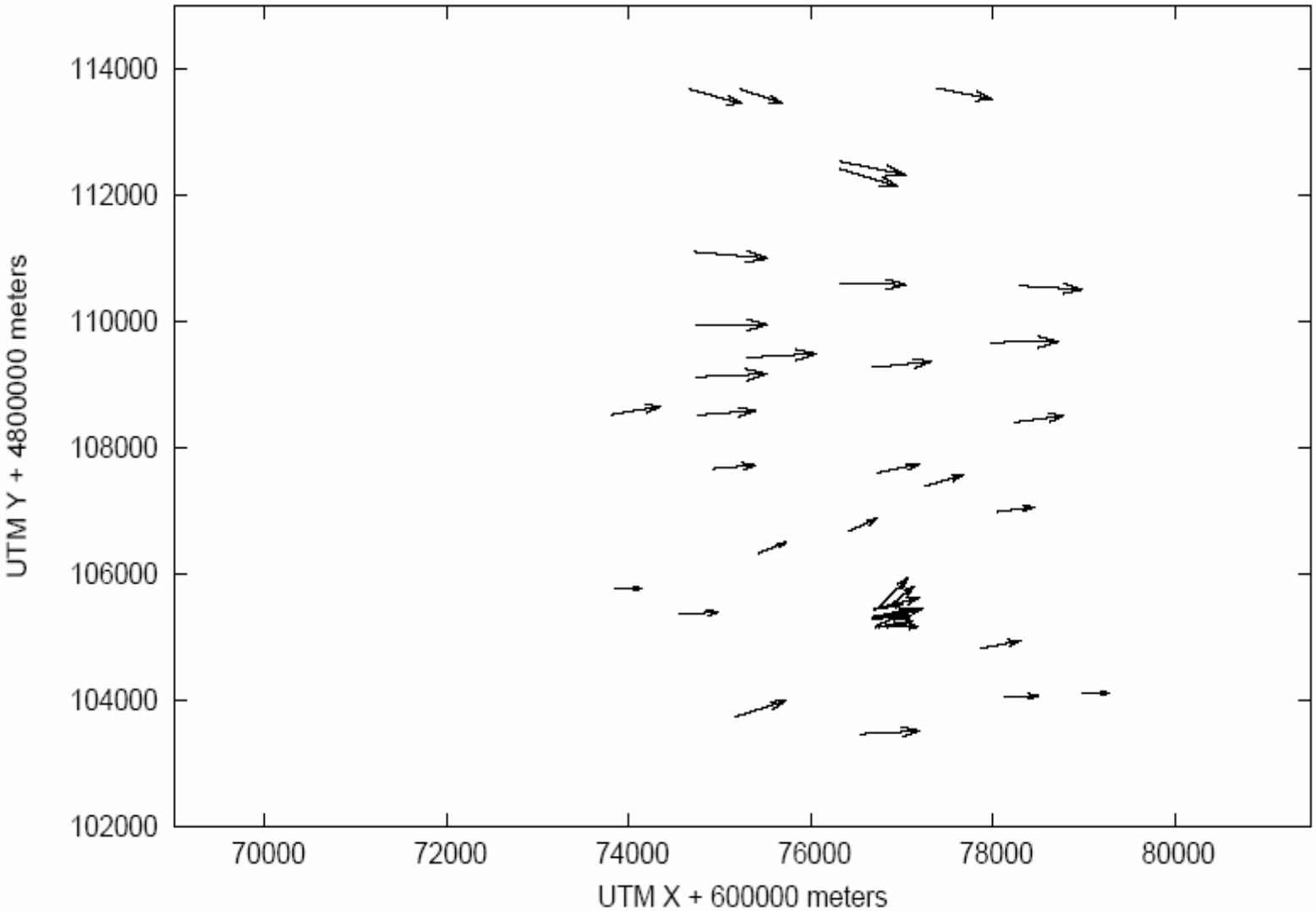
OrbView-3 10-8-2004 Orthorectified



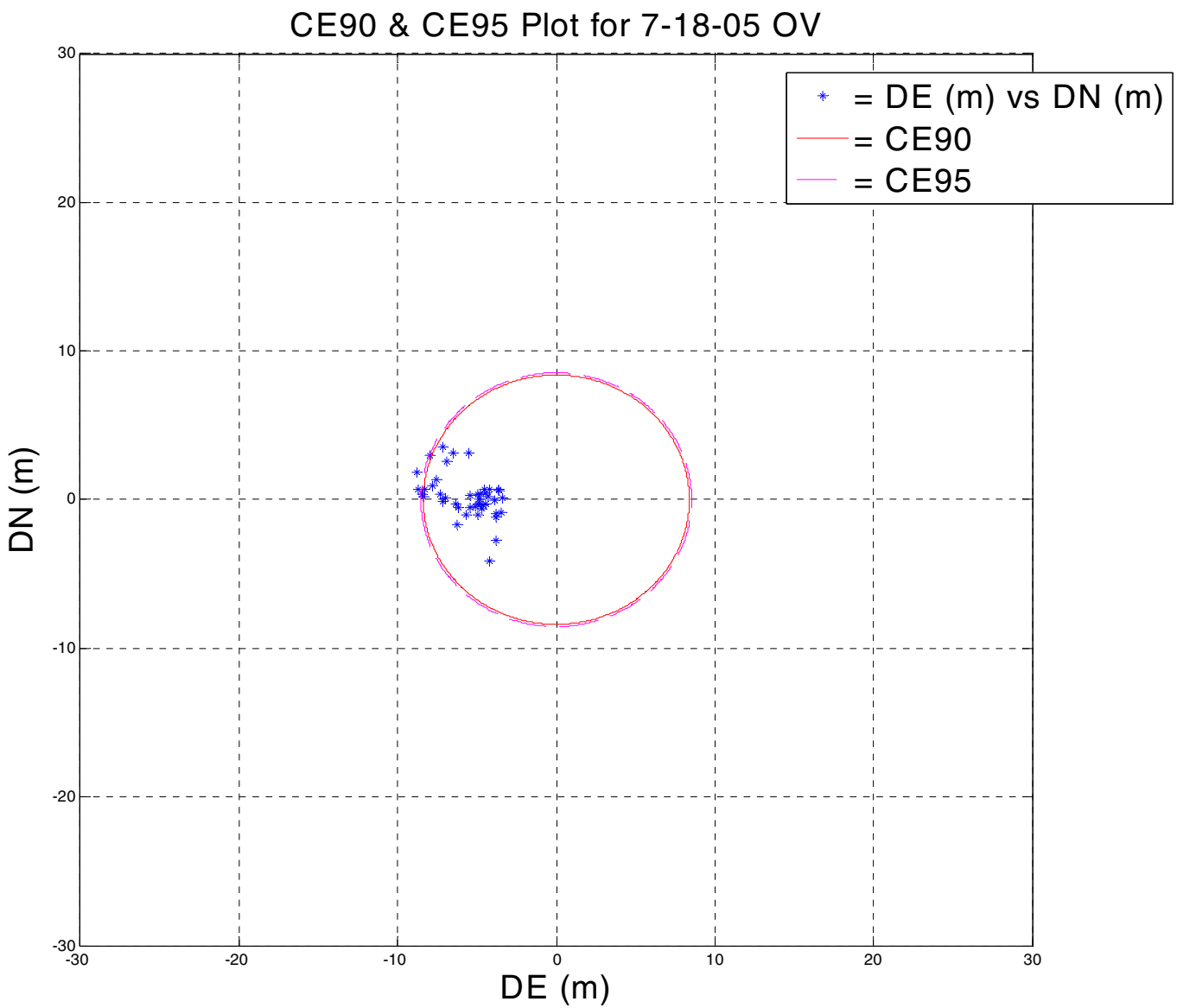
OrbView-3 10-8-2004 Orthorectified (CE90 = 12.6743 m & CE95 = 13.0767 m)



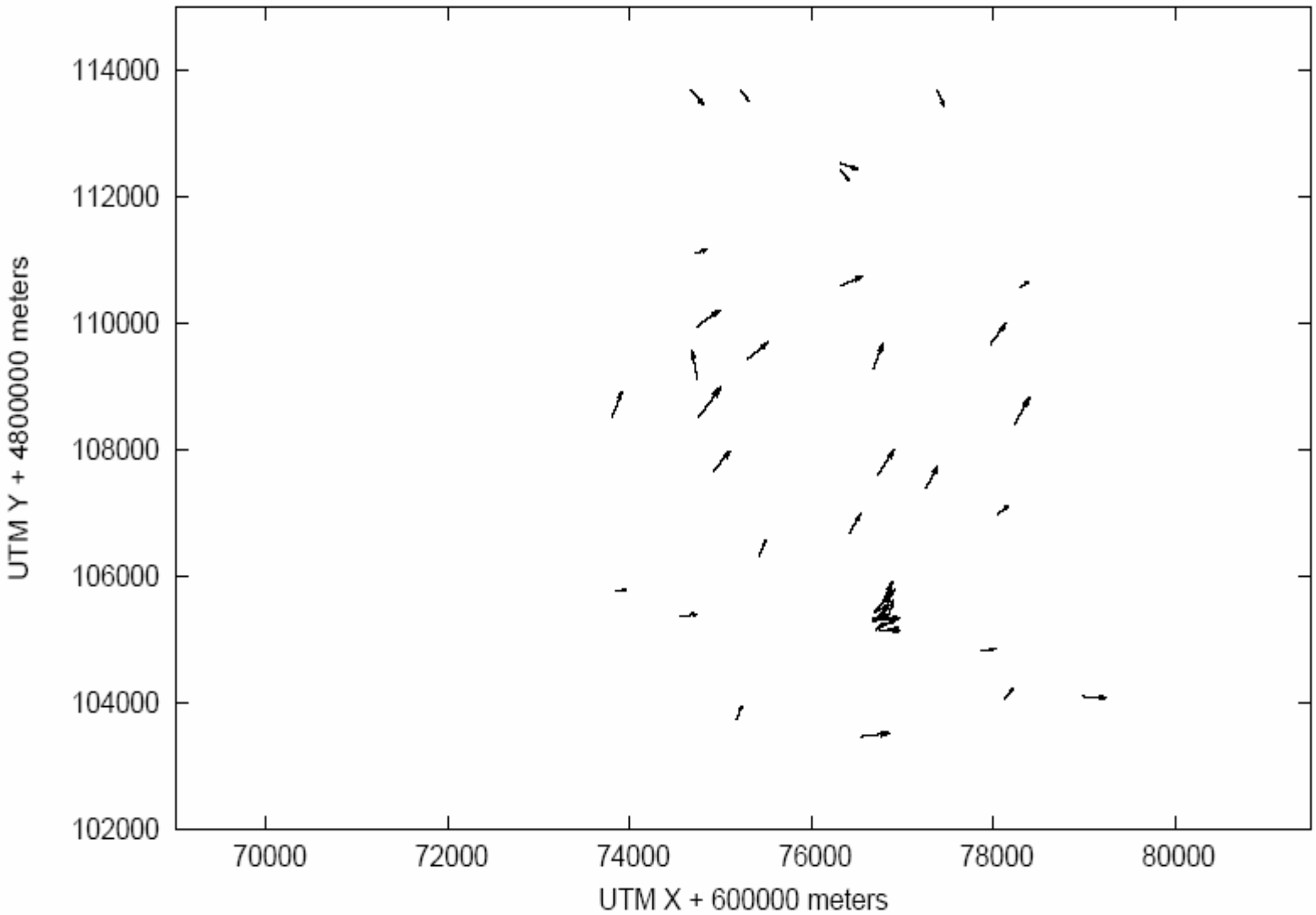
OrbView-3 7-18-2005 Orthorectified



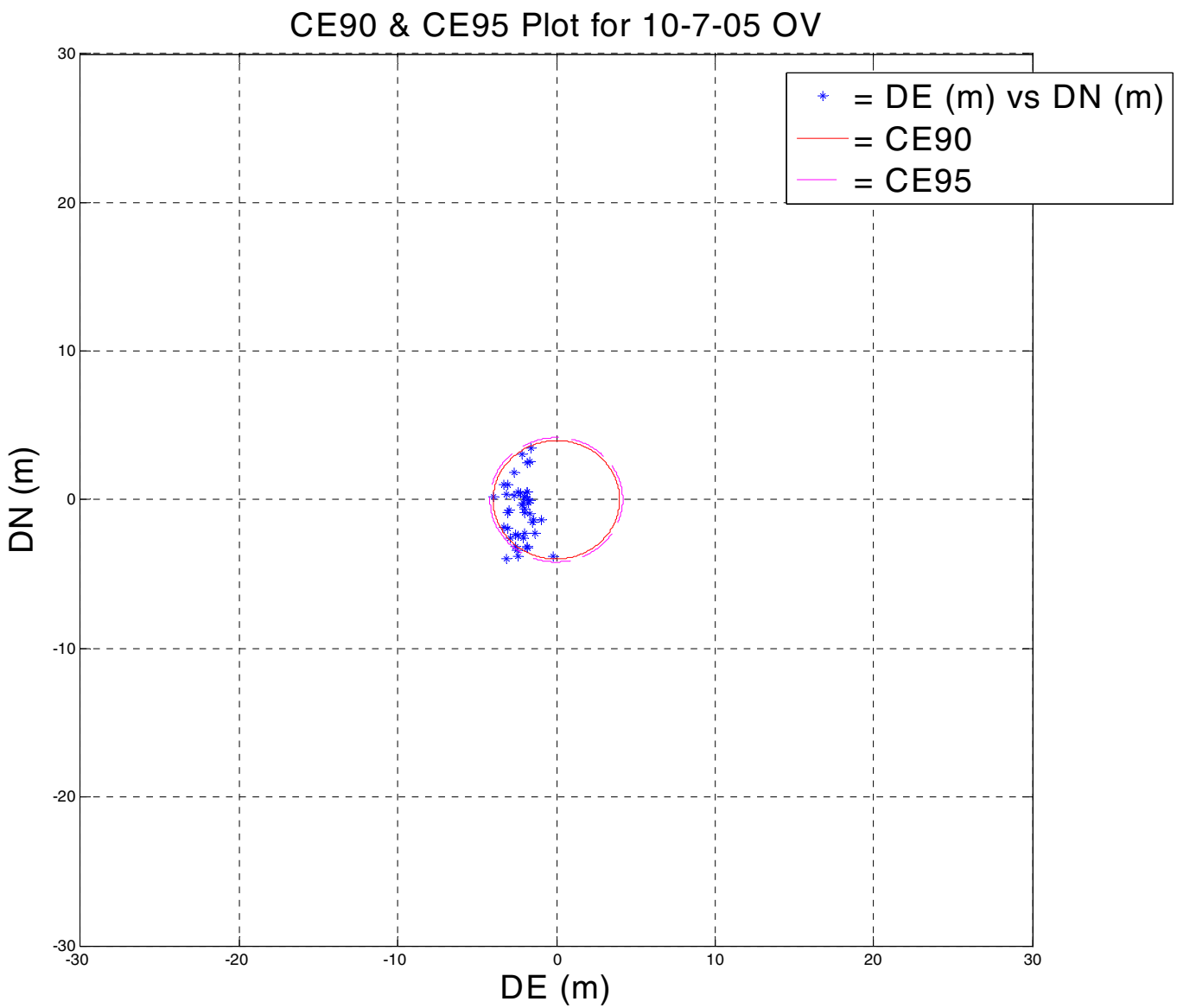
OrbView-3 7-18-2005 Orthorectified (CE90 = 8.3848 m & CE95 = 8.5358 m)



OrbView-3 10-7-2005 Orthorectified



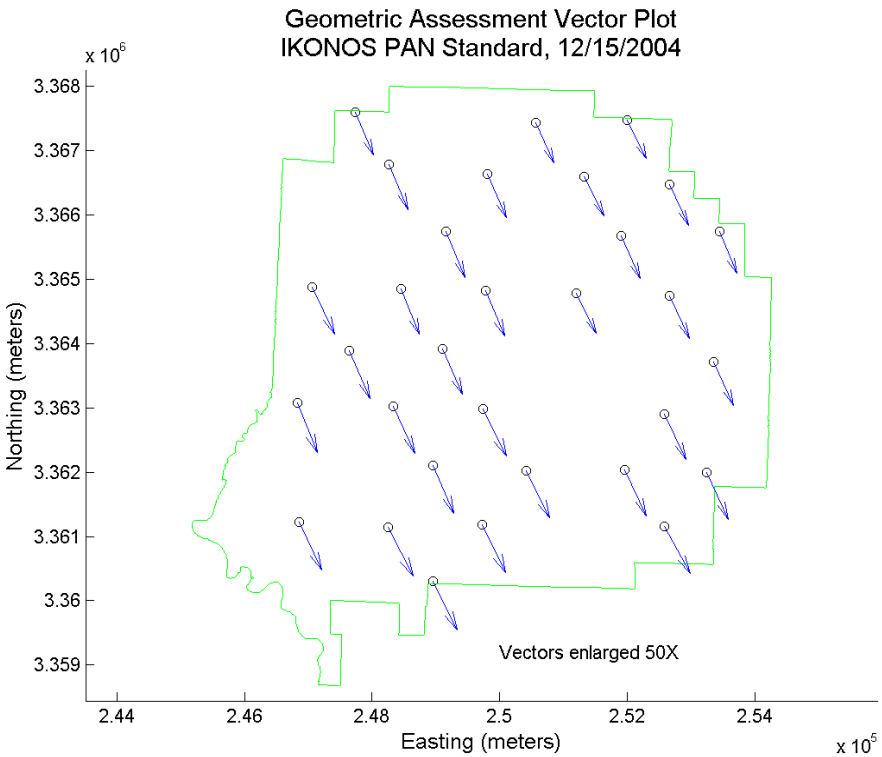
OrbView-3 10-7-2005 Orthorectified (CE90 = 3.9851 m & CE95 = 4.1801 m)



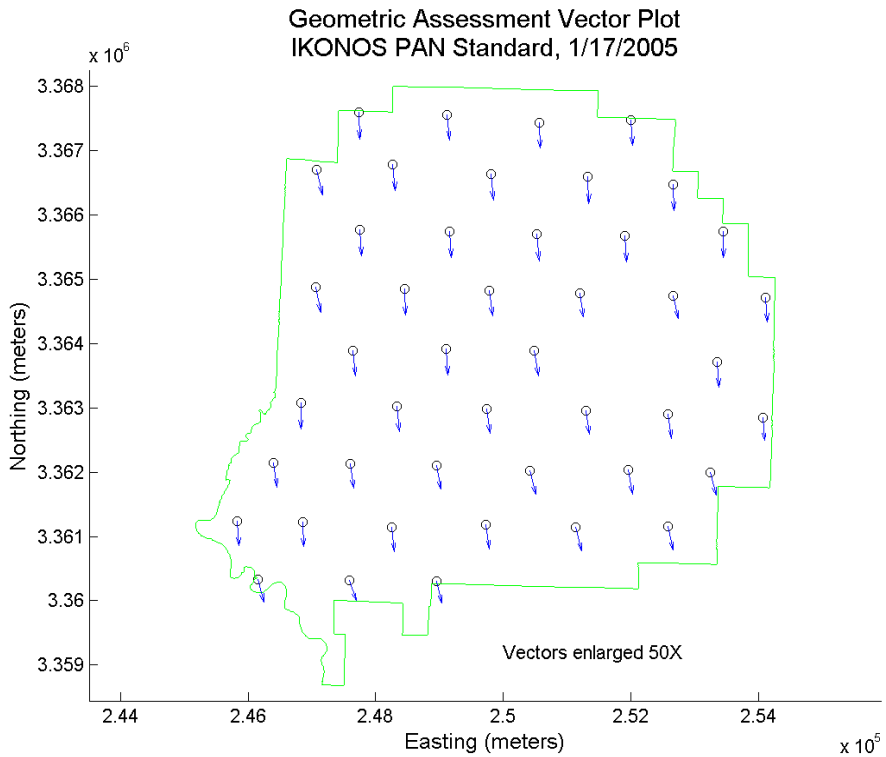
SSC – IKONOS *Geo* PAN

Stennis Space Center

15 DEC 2004	
CE_{90}:	16.72 m
CE_{95}:	17.00 m
Circular Standard Error:	0.81 m



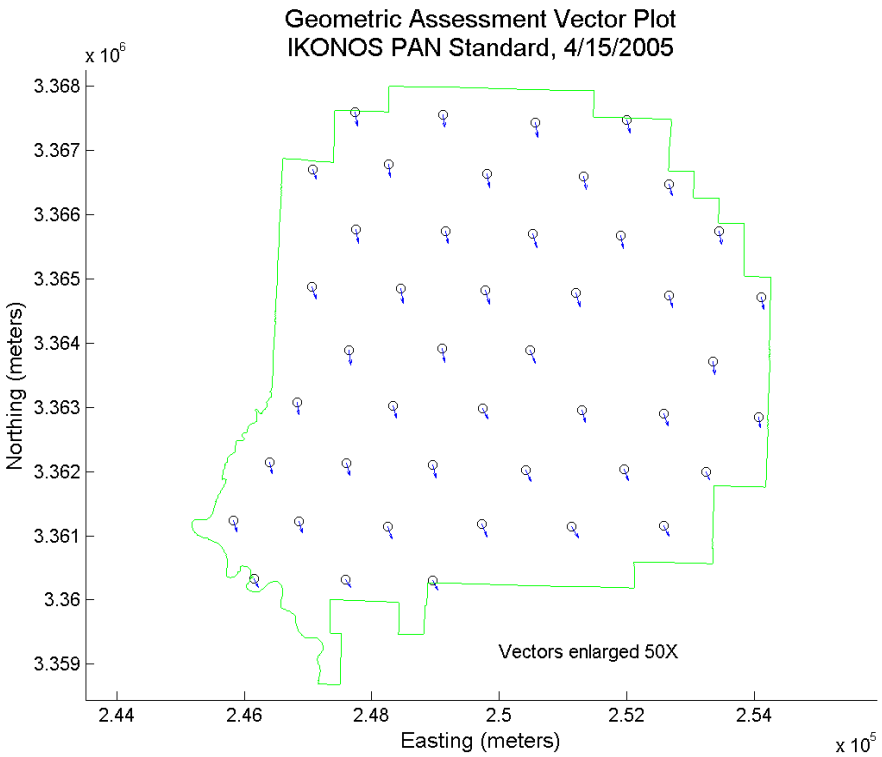
17 JAN 2005	
CE_{90}:	8.18 m
CE_{95}:	8.29 m
Circular Standard Error:	0.49 m



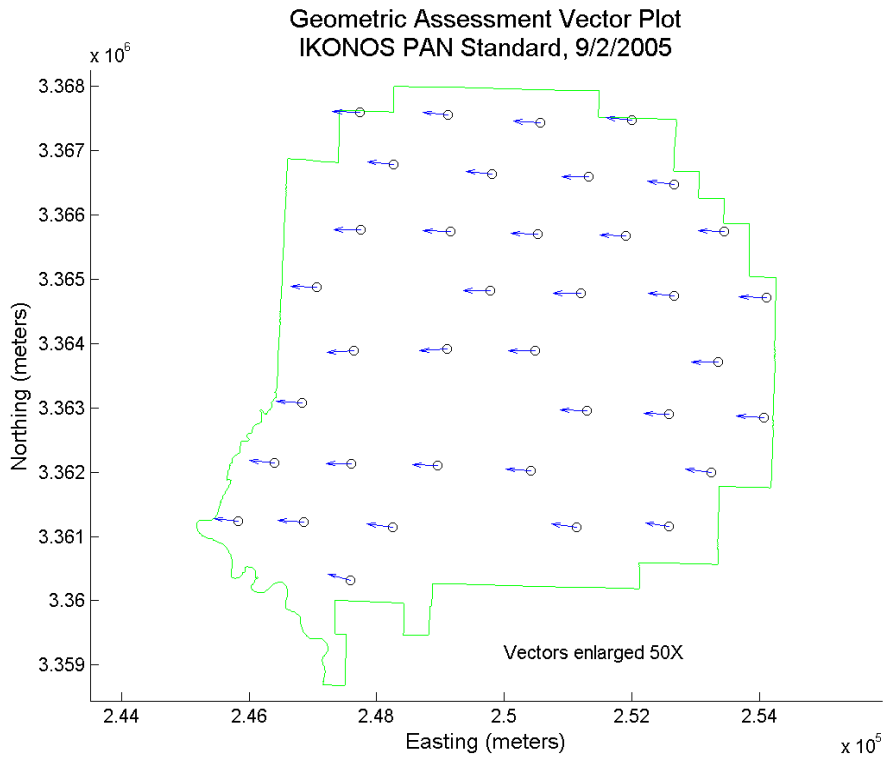
SSC – IKONOS *Geo* PAN

Stennis Space Center

15 APR 2005	
CE_{90}:	4.51 m
CE_{95}:	4.60 m
Circular Standard Error:	0.44 m



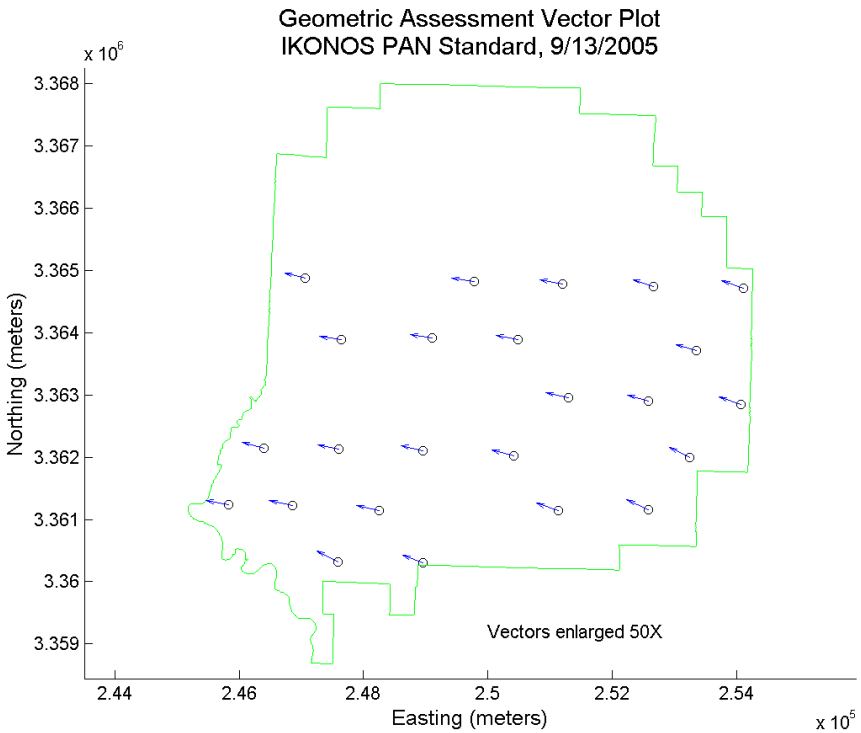
2 SEP 2005	
CE_{90}:	8.59 m
CE_{95}:	8.61 m
Circular Standard Error:	0.40 m



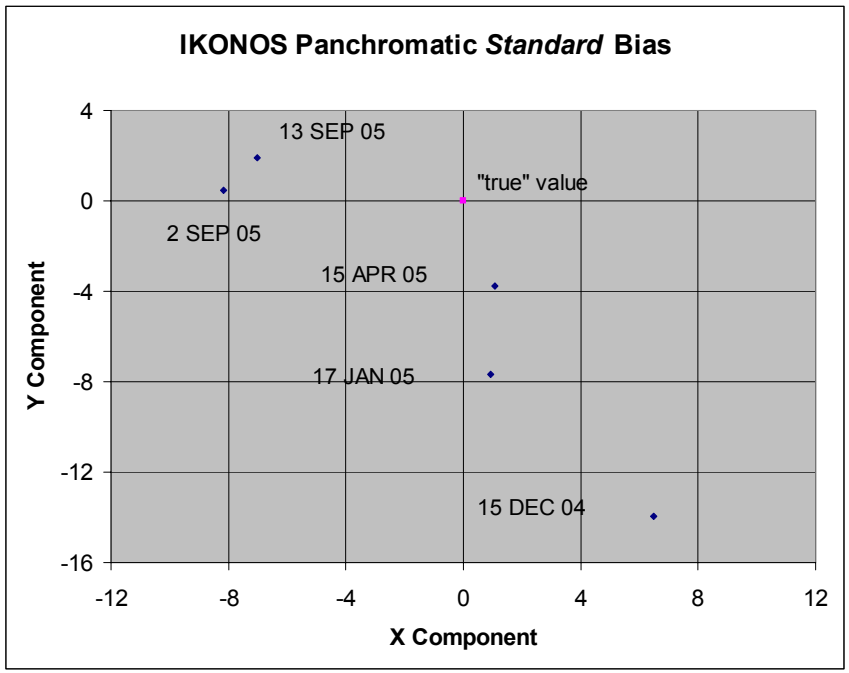
SSC – IKONOS *Geo* PAN

13 SEP 2005

CE_{90}: 7.62 m
CE_{95}: 7.74 m
Circular Standard Error: 0.49 m



IKONOS – No Clear Bias Trend



Extended Summary for 2006 Geopositional Assessments -South Dakota State University-

OrbView-3

Date	Mean Northing Error	Northing Error Standard Deviation	Mean Easting Error	Easting Error Standard Deviation	Mean Error	Error Standard Deviation	Northing RMSE	Easting RMSE	RMSE	CE_{90}	CE_{95}
8/30/2004	9.8228	1.0682	-3.3512	1.3142	10.4526	1.1374	9.8794	3.5942	10.5129	11.7554	12.4592
10/8/2004	11.161	1.2401	-0.2337	1.2379	11.2295	1.2469	11.2281	1.2459	11.297	12.6743	13.0767
7/18/2005	0.2067	1.4499	-5.6424	1.6348	5.8175	1.6629	1.4482	5.8693	6.0453	8.3848	8.5358
10/7/2005	-0.7442	1.8939	-2.2215	0.7126	2.9552	0.8803	2.0147	2.3305	3.0806	3.9851	4.1801

QuickBird - Panchromatic Band

Date	Mean Northing Error	Northing Error Standard Deviation	Mean Easting Error	Easting Error Standard Deviation	Mean Error	Error Standard Deviation	Northing RMSE	Easting RMSE	RMSE	CE_{90}	CE_{95}
8/30/2004	5.174	0.4462	25.2305	0.8804	25.7608	0.8345	5.1927	25.2455	25.774	26.6623	26.9906
10/5/2004	5.8763	1.1221	23.7566	0.8954	24.4978	0.8938	5.9801	23.7731	24.5137	25.6153	25.9286
6/22/2005	-0.0415	0.5975	15.294	1.3369	15.3058	1.3328	0.5921	15.351	15.3624	16.7135	17.3145
10/18/2005	-1.8816	0.9526	-12.0947	1.2938	12.2848	1.2085	2.1041	12.1621	12.3428	13.5985	13.8037

QuickBird - Multispectral Band

Date	Mean Northing Error	Northing Error Standard Deviation	Mean Easting Error	Easting Error Standard Deviation	Mean Error	Error Standard Deviation	Northing RMSE	Easting RMSE	RMSE	CE_{90}	CE_{95}
8/30/2004	4.7736	0.5806	25.5976	0.7466	26.0462	0.7115	4.808	25.6083	26.0557	26.861	26.9368
10/5/2004	5.1087	0.8253	24.3941	0.9249	24.9354	0.9563	5.1734	24.4112	24.9534	25.9796	26.2656
6/22/2005	-1.4035	0.6809	15.9864	1.6215	16.0621	1.6209	1.5566	16.0666	16.1418	17.9719	18.3163
10/18/2005	-3.2157	0.9717	-11.3015	1.142	11.804	0.9738	3.3561	11.3577	11.8432	13.3361	13.5476

NOTE: All data is measured and calculated in meters; measurements are based around 44 GCPs in and around Brookings, SD; and three different individuals were involved in the analysis of each scene.

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14. ABSTRACT
The geolocational accuracy of products from the IKONOS, QuickBird, and OrbView-3 sensors was evaluated using two test sites: one developed in and around Brookings, SD, and one near Stennis Space Center, MS. Both of these relatively flat sites host over 100 ground control points surveyed to an accuracy of approximately 5 cm. They provide robust locations to test the basic geolocational accuracy of a variety of spaceborne and aircraft sensor systems. Imagery of both test sites was acquired by these three sensors in 2004 and in 2005; several products from each sensor, ranging from basic datasets through orthorectified imagery, were analyzed at Stennis Space Center and at South Dakota State University. While direct comparisons between sensors and products are difficult because of differing processing schemes, results indicate that these products tend to display stated levels of accuracy.

15. SUBJECT TERMS
geometric characterization, IKONOS, QuickBird, OrbView, geolocational accuracy

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